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UNITED STATES DEPARTMENT OF AGRICULTURE

In Cooperation with the
Oregon, Washington, and Utah Agricultural Experiment Stations

DEPARTMENT BULLETIN No. 1173



Washington, D. C.



September, 1923

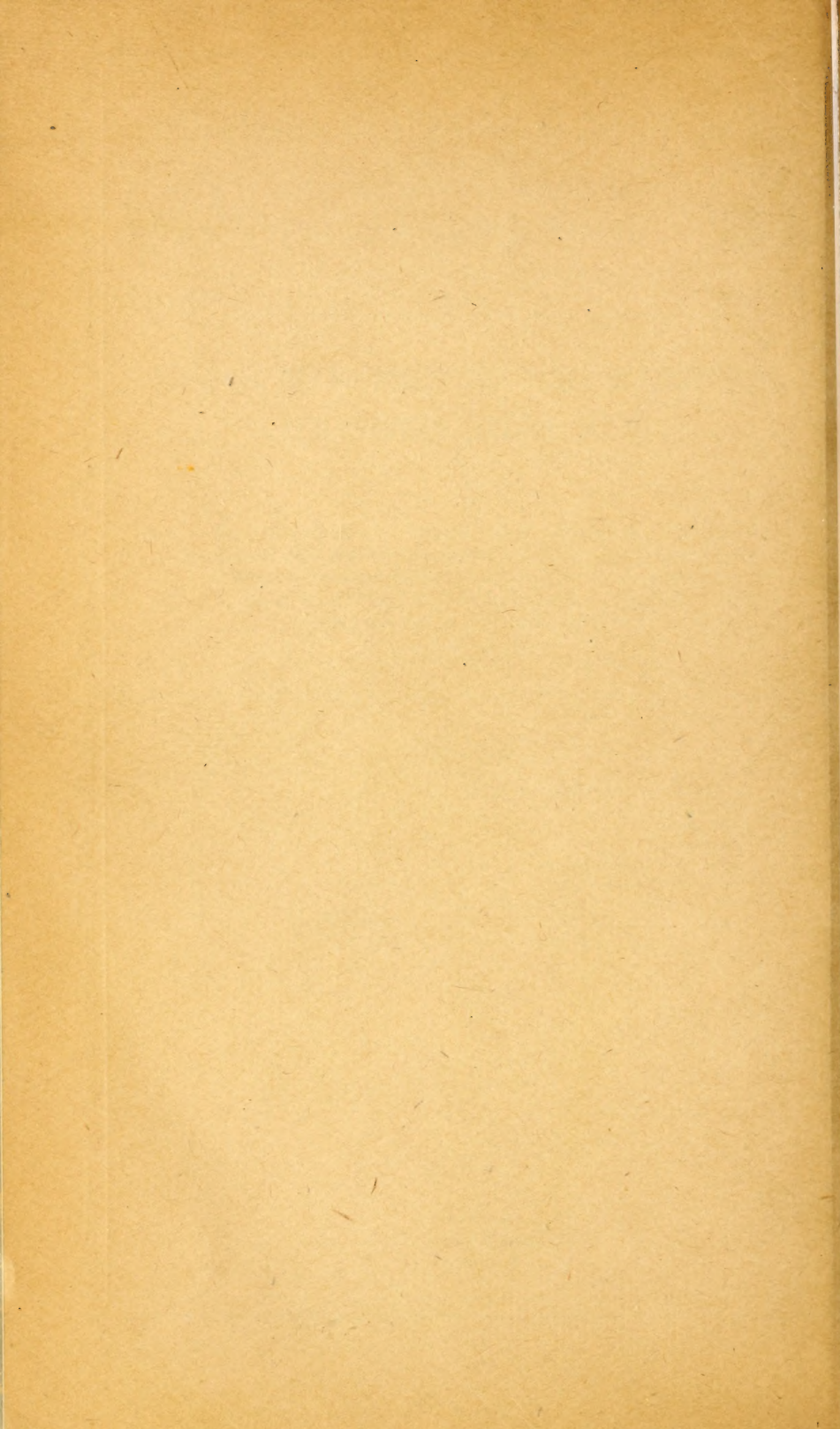
EXPERIMENTS IN WHEAT PRODUCTION ON THE DRY LANDS OF THE WESTERN UNITED STATES

By

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IMPORTANCE OF WHEAT IN THE FAR WEST.

In the agricultural development of the dry lands of the far West, wheat has been the pioneer crop. For this there are several reasons. In sections of high altitude or cool climate, where the winters are not too severe, winter wheat usually will produce more pounds of grain per acre than any other crop, barley being its closest competitor in this respect. Wheat is a crop of wide adaptation, and its price is subject to less fluctuation from year to year than that of other cereals. It always is readily salable, and its value is high in proportion to its bulk. These facts have made wheat a crop of great value to the new settler, who often must haul his crops long distances to market.

Wheat is the most important farm crop grown in the far western United States north of the thirty-seventh parallel of latitude, or the southern boundary of Kansas, Colorado, and Utah. In sections west of the Rocky Mountains where the precipitation is less than 15 inches, it is the only crop grown commercially to any extent except where irrigation is practiced. Even on some of the irrigated lands wheat is quite extensively grown. In general, however, on the irrigated lands, wheat has been largely replaced by such crops as alfalfa, clover, and sugar beets.

Despite its local importance, the total wheat crop produced in the far northwestern United States is not great when compared with the production in the Middle Western and North-Central States. Table 1 shows the average annual production of wheat by 10-year periods since 1881 in the States of Idaho, Washington, Oregon, California, and Utah. The production of wheat in Nevada is unimportant. No statistics are available for Washington, Idaho, and Utah prior to 1882.

Between 1869 and 1879, from 2,000,000 to 8,000,000 bushels of wheat were produced annually in Oregon. In California the annual production of wheat between 1869 and 1879 ranged from 14,000,000 to 40,000,000 bushels. The marked decrease in wheat production in California during the last two decades no doubt can be attributed largely to the fact that farmers have found barley more profitable in certain sections of that State where wheat at one time was practically the only crop produced. On the dry lands in the eastern portions of Oregon and Washington the production of wheat has increased greatly during the last 20 years, although the increase in total production in Oregon has been comparatively slight because wheat has been largely replaced by other crops in the longer settled and more humid Willamette Valley. Nearly all of the wheat produced in Washington is grown in the eastern half of the State.

TABLE 1.—Average annual production of wheat in the States of Idaho, Washington, Oregon, California, and Utah by 10-year periods from 1881 to 1920.¹

Period.	Wheat production (bushels).				
	Idaho.	Washington.	Oregon.	California.	Utah.
1881 to 1890.....	² 1,093,000	² 6,332,000	13,555,000	37,651,000	² 1,783,000
1891 to 1900.....	4,326,000	16,115,000	12,948,000	32,818,000	2,997,000
1901 to 1910.....	8,940,000	29,150,000	14,996,000	20,079,000	4,826,000
1911 to 1920.....	16,836,000	42,213,000	18,081,000	2,902,000	6,106,000

¹ Annual figures of wheat production for 1881 are not available for Idaho, Washington, and Utah.

² Nine-year average, 1882 to 1890.

Farm practice is usually the outgrowth of necessity. In the States of Washington, Oregon, Idaho, and Utah climatic conditions are such that successful wheat production on dry lands is based on alternate years of crop and of clean fallow. In the development of the summer-fallow system in these States, many different methods of cultivating the land have been advocated. Tillage methods practiced by farmers are many and diverse.

In 1904 experiments to determine the effect of different tillage methods on the yield of wheat were begun at Nephi, Utah, in the Great Basin area. These experiments have been conducted cooperatively by the Utah Agricultural Experiment Station and the United States Department of Agriculture since 1908. Similar experiments were begun at Moro, Oreg., in the Columbia Basin, in 1911, and at Lind, Wash., also in the Columbia Basin, in 1916, by the agricultural experiment stations of these States in cooperation with the United States Department of Agriculture. The location of these stations is shown in Figure 1. A wide range of crop experiments is conducted at these stations, but in this bulletin only the results of the tillage experiments and those on the rate, date, and depth of sowing wheat grown after fallow will be presented. Diagrams showing the platting of the stations at Moro, Oreg., and Lind, Wash., are presented in Figures 2 and 3.

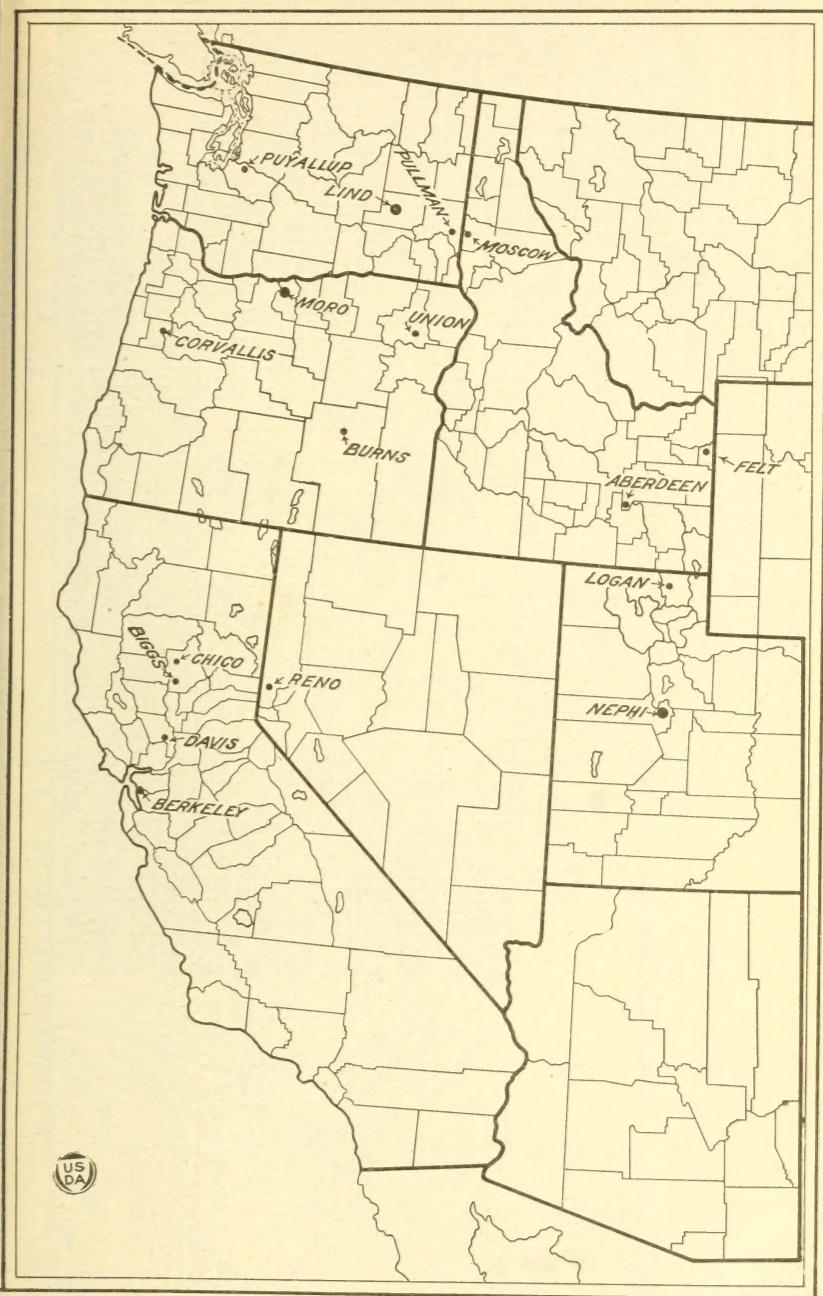
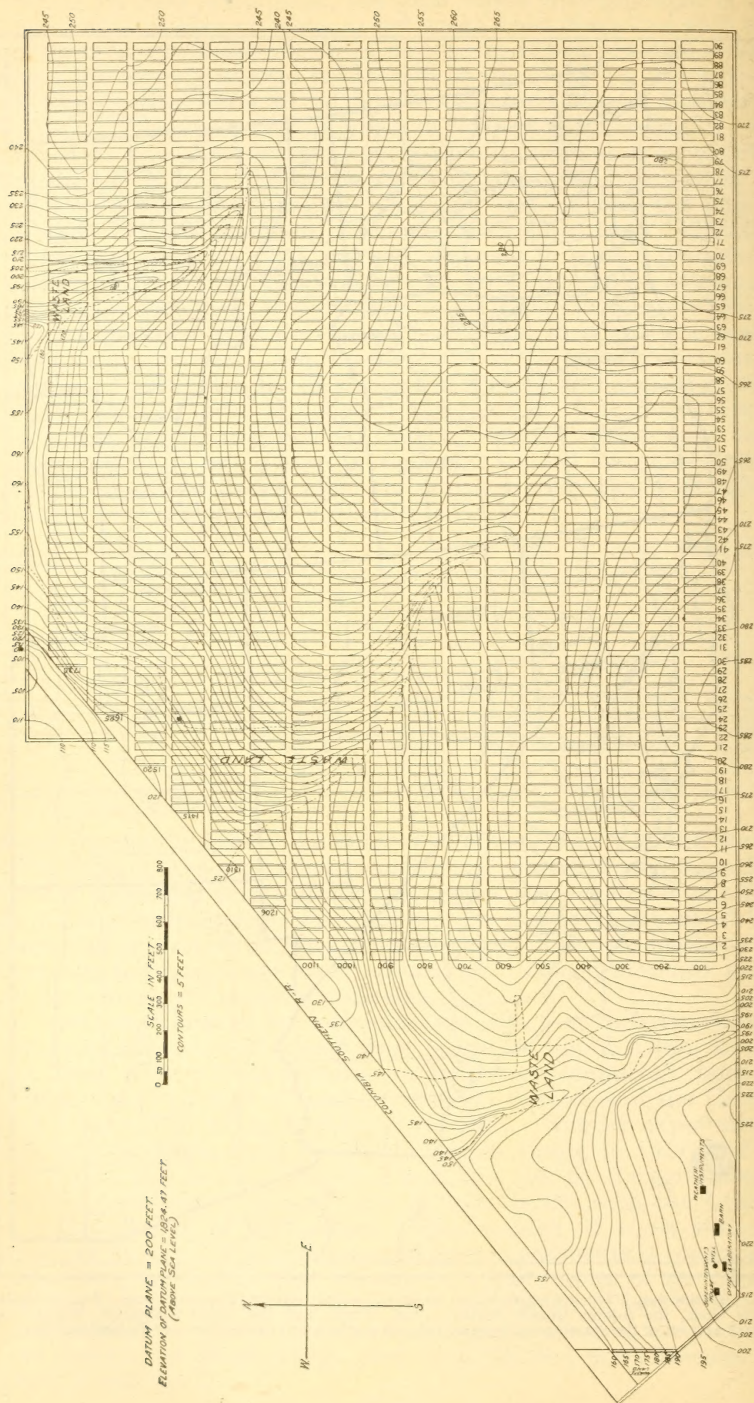


FIG. 1.—Outline map of seven Western States, showing the location of the Sherman County Branch Station, Moro, Oreg., the Adams Branch Station, Lind, Wash., and the Nephi Substation, Nephi, Utah, as well as some of the State agricultural experiment stations and substations and Federal stations.



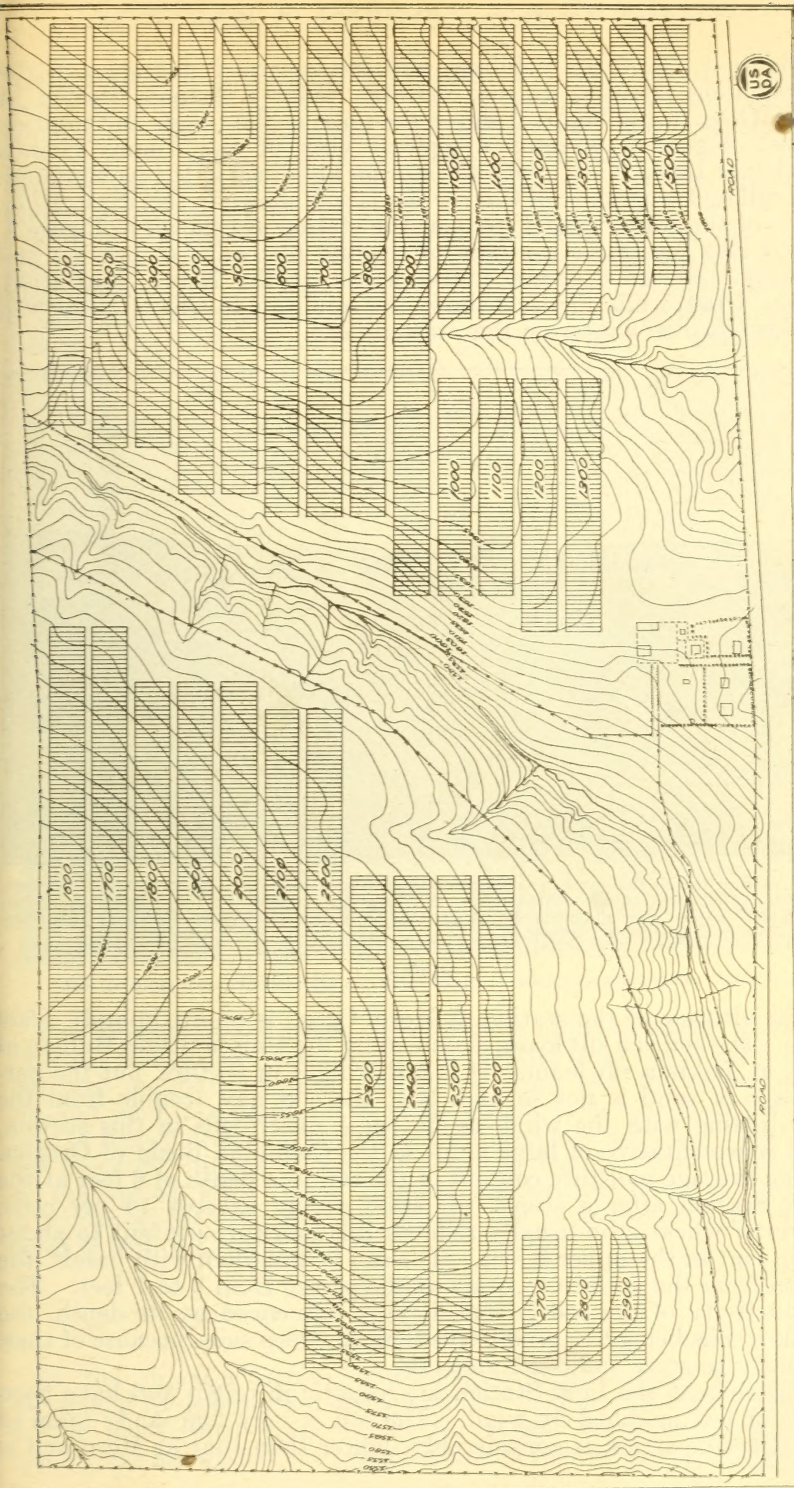


FIG. 3.—Contour map of the Adams Branch Station, Lind, Wash., in 1918, looking north, showing deep ravine in the center with the experimental plots on either side. The station occupies the southern half of section 32-18-34.

Figure 4 shows the buildings and the general topography of the surrounding country at the Sherman County Branch Station at Moro, Oreg., while Figure 5 shows the plats in the tillage and rotation series. Figure 6 presents a general view of the Adams Branch Station at Lind, Wash., with the station buildings in the background. The rolling topography of this section is well shown in this illustration. Some of the winter-wheat plats at the station are shown in Figure 7, which also illustrates the plan of seeding roadways to prevent soil blowing. Figure 8 shows winter wheat at the Nephi Substation, Nephi, Utah, while Figure 9 shows the condition in which fall-plowed land is left over winter on this station farm.

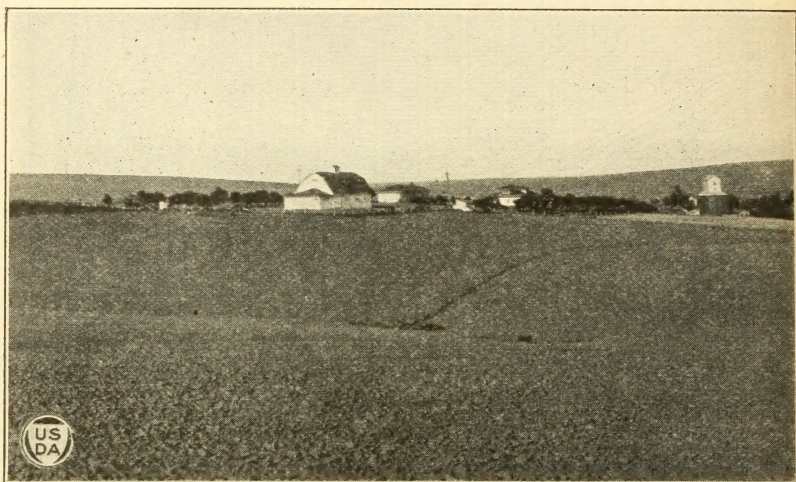


FIG. 4.—Buildings at the Sherman County Branch Station at Moro, Oreg., as they appeared in July, 1922. At left center, barn for stock and hay; at center, office and laboratory; at right center, superintendent's house. The buildings at the extreme right are in the town of Moro. The rolling topography of the surrounding country is shown.

SOILS.

The altitude of the station at Moro, Oreg., is approximately 1,800 feet. The soil is a silt loam, classified by the United States Bureau of Soils as Yakima silt loam. It is rather light in texture, but the percentage of sand is not so high that there is any trouble from the soil drifting with the wind, as do some other soils in this section. It is representative of large areas in the Columbia Basin of Oregon.

The average moisture content of the soil to a depth of 6 feet at the Moro Station after a season of fallow rarely exceeds 14 per cent. A winter-wheat crop usually reduces this moisture content to about 5 per cent in the upper 6 feet. The soil is underlain with basalt, the depth from the surface to this basalt varying from 2 to 7 feet. The productivity of the soil is considerably influenced by its depth, the shallow soils being less productive than the deep soils, because of their inability to store sufficient moisture.

The soils at the Lind Station are basaltic in origin and have been more or less modified by wind. The soil, a very fine sandy loam of the Ritzville series, is considerably lighter than that at Moro and is

more subject to drifting or blowing by the wind. The soil depth varies from 10 to 50 feet, and the texture is remarkably uniform throughout the entire depth. The topography, like that at Moro, is rolling, the entire dry-farming area of the Columbia River Basin being a plateau cut by dry canyons or coulees. The altitude of the station at Lind is 1,600 feet.

During the years that the experiments herein reported were conducted the moisture at Lind has been far below normal and has not been sufficient to penetrate the soil to a greater depth than 4 feet or to raise the moisture content above 10 per cent, even after a season of fallow. The moisture content after growing a crop of winter wheat is about 3.8 per cent in the upper 4 feet of soil.



FIG. 5.—Some of the experimental plats at the Sherman County Branch Station, Moro, Oreg.

The altitude of the Nephi Substation is approximately 5,300 feet. The soil is a rather heavy clay loam derived from the weathering of adjacent mountain ranges. Below the third foot the percentage of silt and sand increases, and at about the seventh foot there is a stratum of heavy blue clay of rather high moisture content. The average moisture content of the first 6 feet is usually about 20 per cent in the spring after being fallowed during the previous summer. A winter-wheat crop usually reduces the moisture content of this layer of soil to about 9 per cent.

CLIMATIC DATA.

PRECIPITATION.

Of the climatic factors influencing crop production the precipitation and its distribution throughout the year are the most important in the dry-farmed areas of the far West. High yields of wheat usually are associated with years of heavy rainfall during the growing

season, or the months of April, May, and June. Table 2 shows the precipitation by months and the total annual precipitation at Moro, Lind, and Nephi. The records at Moro are for the years 1905 to 1920, inclusive; at Lind, for the years 1916 to 1920, inclusive; and at Nephi for the years 1898 to 1920, inclusive. In this connection it should be borne in mind that the precipitation at Lind during this period is much below normal. In the 9-year period from 1897 to 1906, inclusive, the average precipitation at Lind was 11.8 inches as compared with 7.22 inches in the period of these experiments.



FIG. 6.—The Adams Branch Station at Lind, Adams County, Wash., as it appeared in 1920. Note the rolling topography of the country.

TABLE 2.—Average monthly and annual precipitation, at Moro, Oreg., Lind, Wash., and Nephi, Utah, for the years stated.

Month.	Average precipitation (inches).			Month.	Average precipitation (inches).		
	Moro, Oreg., 1905 to 1920.	Lind, Wash., 1916 to 1920.	Nephi, Utah, 1898 to 1920.		Moro, Oreg., 1905 to 1920.	Lind, Wash., 1916 to 1920.	Nephi, Utah, 1898 to 1920.
January.....	1.58	0.74	1.15	August.....	0.26	0.30	0.92
February.....	1.03	.67	1.24	September.....	.88	.27	1.01
March.....	.82	.57	1.61	October.....	.79	.35	1.24
April.....	.68	.97	1.34	November.....	1.75	1.02	.89
May.....	1.10	.87	1.70	December.....	1.64	.95	.98
June.....	.78	.29	.57				
July.....	.21	.22	.68	Total.....	11.52	7.22	13.33

During the period of the experiments Nephi had the highest annual precipitation and Lind the lowest. More of the precipitation at Nephi was in the form of snow, although there was always some snow at Moro and at Lind. In case of a sudden thaw with frozen soil, a part of the winter precipitation at Moro and Lind sometimes is lost as run-off on account of the rolling topography of the land.

The average rainfall for April, May, and June at Lind was 2.13 inches, or 29.5 per cent of the annual precipitation. At Moro the average rainfall for these three months was 2.6 inches, or 22.5 per cent of the annual precipitation. At Nephi the average rainfall for these months was 3.61 inches, or 27.1 per cent of the annual precipitation.

EVAPORATION.

At Nephi and at Moro a record of the evaporation from a free water surface was kept. No record was kept at Lind, but records elsewhere indicate evaporation to be at least equal to if not greater



FIG. 7.—A portion of the Adams Branch Station at Lind, Wash., showing winter-wheat plats and the method of seeding roadways to prevent soil blowing.

than that at Moro. At Nephi this record was kept since 1908 and at Moro since 1911. Table 3 shows the average evaporation from a free water surface at each of the two stations.

TABLE 3.—Average monthly evaporation from a free water surface in the seven months from April to October, inclusive, at Moro, Oreg., and Nephi, Utah, for the years stated.

Month.	Average evaporation (inches).		Month.	Average evaporation (inches).	
	Moro, Oreg., 1911 to 1920.	Nephi, Utah, 1908 to 1920.		Moro, Oreg., 1911 to 1920.	Nephi, Utah, 1908 to 1920.
April.....	4.65	4.219	September.....	4.63	6.330
May.....	6.57	6.775	October.....	2.81	3.403
June.....	8.16	8.934			
July.....	9.71	9.662	Total.....	44.88	48.373
August.....	8.35	9.050			

TEMPERATURE.

Table 4 shows the mean monthly temperatures at Moro for a 10-year period and at Nephi for a 13-year period. At Nephi temperatures are recorded only from April 1 to November 1 of each year. Temperature records at Lind are not available for the entire period of these experiments, but temperatures for a former period, taken from United States Weather Bureau records kept in the same form, are given.



FIG. 8.—Plats of winter wheat at the Nephi Substation, Nephi, Utah. The station lies on a transverse ridge in a narrow valley between two ranges of mountains.

TABLE 4.—Average mean temperatures, by months, at Moro, Oreg., Lind, Wash., and Nephi, Utah.

Month	Average mean temperatures (°F.).			Month.	Average mean temperatures (°F.).		
	Moro, Oreg., 1911 to 1920.	Lind, Wash. ¹	Nephi, Utah, 1908 to 1920.		Moro, Oreg., 1911 to 1920.	Lind, Wash. ¹	Nephi, Utah, 1908 to 1920.
January.....	30.2	30.1	.....	July.....	68.1	73.7	71.4
February.....	33.2	32.5	.....	August.....	67.5	73.7	70.2
March.....	41.2	41.1	.....	September.....	54.9	62.3	60.9
April.....	47.1	50.9	45.4	October.....	48.4	51.7	47.3
May.....	52.8	58.5	53.6	November.....	38.5	39.6	.....
June.....	61.5	65.3	63.7	December.....	31.5	30.6	.....

¹ Compiled from records of the United States Weather Bureau covering an earlier period than is given for the other stations. Summary of the climatological data of the United States by sections. Reprint of section 20, eastern Washington.

The average frost-free period at each station is shown in Table 5. Frosts in the late spring or early autumn rarely damage the wheat crop at these stations, though severe winter temperatures may sometimes cause winterkilling of fall-sown grain. During the period for which data are available the latest spring frost recorded at Lind was on June 8, in 1901, and the earliest autumn frost on September 27, in 1901. The latest frost in the spring recorded at Moro was on June 1, in 1917; the earliest autumn frost on September 3, in 1912. The latest spring frost at Nephi was on June 22, in 1916, and the earliest autumn frost on September 4, in 1912.



FIG. 9.—Fall-plowed land at the Nephi Substation in 1909, to be left rough during the winter in order to catch rain and snow.

TABLE 5.—Frost-free period at Moro, Oreg., Lind, Wash., and Nephi, Utah, for the years specified.

Year.	Lind, Wash. ¹	Year.	Moro, Oreg.	Nephi, Utah.	Year.	Moro, Oreg.	Nephi, Utah.
	<i>Days.</i>		<i>Days.</i>	<i>Days.</i>		<i>Days.</i>	<i>Days.</i>
1899.....	150	1910.....	142	142	1916.....	144	108
1901.....	106	1911.....	162	113	1917.....	137	105
1902.....	170	1912.....	127	96	1918.....	158	100
1903.....	132	1913.....	171	143	1919.....	135	112
1904.....	115	1914.....	108	96	1920.....	136	115
1905.....	142	1915.....	211	93	1921.....	107	.....
Average...	136	.....	.....	.....	.....	145	111

¹ United States Weather Bureau data.

TILLAGE EXPERIMENTS.

TREATMENT OF LAND BEFORE PLOWING.

All the land at the stations at Moro and Lind was in crop at the time these stations were established. No experiments, therefore, have been conducted at either station on the best methods of preparing sod ground for wheat. At Nephi the station was located on virgin land.

After removing a grain crop the farmer may do one of several things to his fields. He may (1) disk the stubble land in the fall, (2) burn the stubble in the fall or spring, (3) plow the land in the fall, (4) leave the stubble standing during the winter and disk the land in the spring, or (5) leave the land uncultivated until it is plowed in the spring. Each of these practices is followed by farmers in Oregon, Washington, Idaho, and Utah. Plowing for fallow usually is done in the spring by most farmers in these States.

FALL DISKING.

Experiments have been conducted at each of the three stations to determine the value of fall disking when the land is to be spring plowed. These results are summarized in Table 6 and are shown graphically in Figure 10. The acre yields reported in this table are based on yields of single tenth-acre plats at each of the three stations.

TABLE 6.—*Annual and average yields of Turkey winter wheat on land disked in the fall and plowed early in the following spring for fallow and on land plowed in the spring but not disked in the fall, at Moro, Oreg., Lind, Wash., and Nephi, Utah, in varying periods from 1913 to 1921.*

Station and treatment.	Yield per acre (bushels).									
	1913	1914	1915	1916	1917	1918	1919	1920	1921	Average.
Moro, Oreg.:										
Disked in the fall	23.0	25.6	23.6	34.3	21.2	17.3	38.3	25.0	35.5	27.2
Not disked in the fall	25.1	26.9	26.3	41.3	25.0	22.3	38.5	29.7	31.3	29.6
Lind, Wash.:										
Disked in the fall						5.6	12.2	8.3	12.3	9.6
Not disked in the fall						6.2	12.3	9.8	15.7	11.0
Nephi, Utah:										
Disked in the fall				16.0	24.7	11.2	17.3	28.0	35.9	22.3
Not disked in the fall				18.3	31.8	14.5	23.7	27.5	38.4	25.7

Advantages claimed for fall disking are: (1) It kills weeds that may take out moisture after harvest, (2) it permits better penetration of the autumn and winter precipitation by mellowing the surface soil, (3) it covers weed seeds and shattered grain so that they germinate more quickly, (4) it prevents run-off in the early spring, and (5) it hastens the decay of the stubble and other vegetation.

Experiments at the three stations have proved that these advantages are apparent rather than real. Table 6 shows that fall disking actually reduced yields at Moro, Nephi, and Lind. Double disking ordinarily will not kill Russian thistle, one of the troublesome weeds which grows on wheat land after harvest. The moisture determinations at these stations also have shown that disking the stubble land

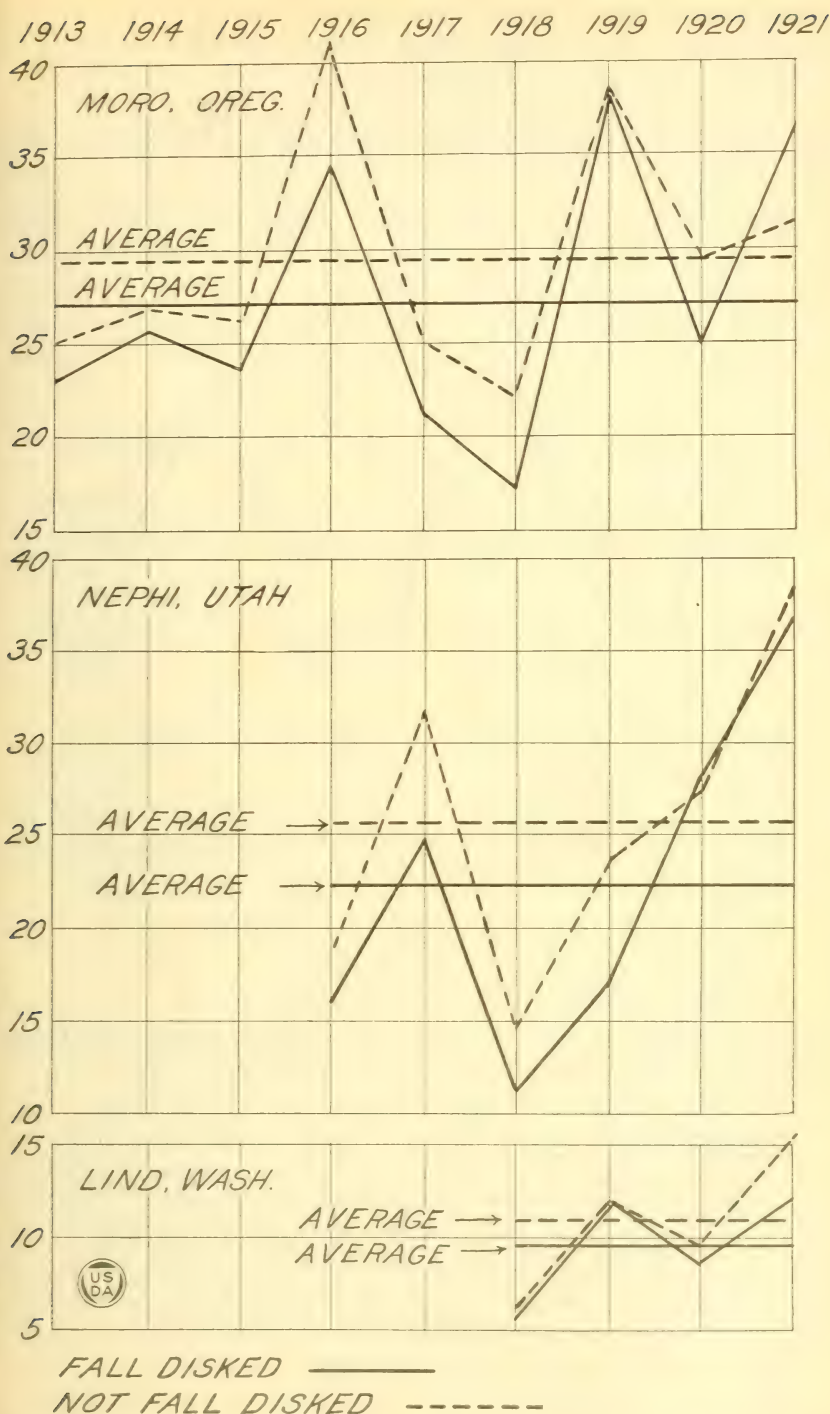


FIG. 10.—Annual and average acre yields, in bushels, of winter wheat in varying numbers of years at Moro, Oreg., Nephi, Utah, and Lind, Wash., when grown after summer fallow for which the ground had been plowed in early spring with the stubble disked or not disked in the previous fall.

in the fall does not aid in better absorption of the autumn and winter precipitation. It more frequently deters moisture penetration by creating a mulch which holds the moisture near the surface and thereby hastens its escape by evaporation. This is especially true if the disking is done when the ground is dry. The standing stubble during the winter is no doubt a factor in increasing soil moisture, as

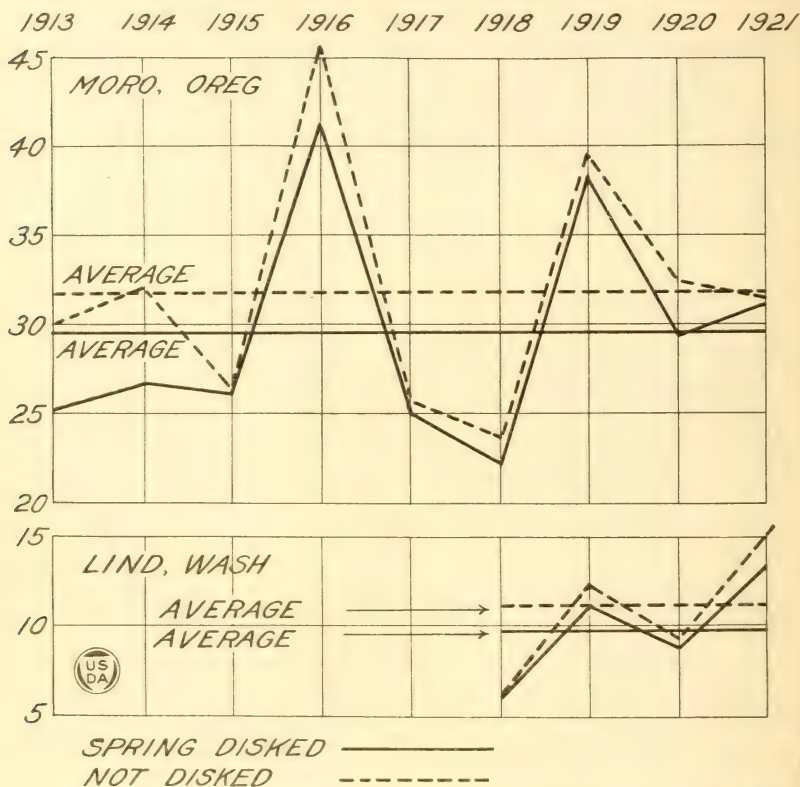


FIG. 11.—Annual and average acre yields, in bushels, of winter wheat in varying numbers of years at Moro, Oreg., and Lind, Wash., when grown after summer fallow for which the ground had been plowed in early spring with the stubble disked or not disked in early spring before plowing.

it helps to hold the snow where it falls and prevents drifting to a considerable extent.

As is shown later, spring disking of the stubble generally proved beneficial if the plowing was done very late in the spring. Fall disking, however, is not a satisfactory substitute for spring disking, because weeds and volunteer grain normally do not get started early enough in the autumn to be destroyed by fall disking. A good double disking in the spring ordinarily will kill all plant growth, which is the chief value of disking.

SPRING DISKING.

Experiments to determine the value of disking in the spring prior to plowing also were conducted at Moro and Lind. The results obtained from these experiments are presented in Table 7 and are shown graphically in Figures 11, 12, and 13. It will be noted from this table that spring disking has significantly increased wheat yields at Moro when the plowing was done as late as June 1. With plowing done in April and early in May there seems to be no advantage in spring disking.

TABLE 7.—*Annual and average yields of Turkey winter wheat on land disked and not disked before plowing at different times in the spring at Moro, Oreg., from 1913 to 1921, and at Lind, Wash., from 1918 to 1921.*

Station, date of plowing, and treatment before plowing.	Yield per acre (bushels).									
	1913	1914	1915	1916	1917	1918	1919	1920	1921	Average.
MORO, OREG.										
Plowed early in April:										
Disked.....	25.1	26.9	26.3	41.3	25.0	22.3	38.5	29.7	31.3	29.6
Not disked.....	30.0	32.0	26.4	45.7	25.7	23.5	39.7	32.8	31.7	31.9
Plowed early in May:										
Disked.....	18.5	27.8	27.5	35.1	22.3	19.2	35.3	25.3	33.7	27.5
Not disked.....	19.0	27.0	24.7	38.0	24.7	24.7	30.0	31.0	29.8	27.7
Plowed early in June:										
Disked.....	23.0	27.7	23.9	34.3	23.1	20.3	32.3	29.0	32.5	27.3
Not disked.....	7.3	21.6	20.5	34.8	24.7	26.0	19.5	25.5	25.2	22.9
LIND, WASH.										
Plowed early in March:										
Disked.....						6.1	11.2	8.7	13.3	9.8
Not disked.....						6.2	12.3	9.8	15.7	11.0
Plowed in mid-April:										
Disked.....						5.9	12.0	8.1	15.0	10.2
Not disked.....						6.0	14.0	9.2	16.3	11.4
Plowed early in June:										
Disked twice (Mar. 1 and Apr. 10)...						5.9	14.3	9.2	13.7	10.8
Disked once (Mar. 1).....						5.8	13.3	8.0	13.0	10.0
Not disked.....						5.3	11.3	5.0	12.3	8.5

BURNING STUBBLE.

In certain sections of heavy rainfall in the eastern parts of Oregon and Washington, the practice of burning the stubble before plowing is quite generally followed by farmers. The stubble usually is burned in the early spring, though some farmers burn it late in the fall. When wheat is harvested with the combined harvester, as is the custom in eastern Oregon and eastern Washington, a large part of the crop growth is left on the land in the form of stubble. Most of the straw which goes through the machine also is left in the field in windrows or piles, to be burned or plowed under. Frequently the stubble and straw are so heavy that much difficulty is experienced in cultivating fallow after they are turned under.

Sufficient experimental data are not available to determine the actual effect on the yield of wheat of burning the stubble. The only experimental data yet available are from results obtained at the Nephi Substation, where this experiment has been in progress during the six years from 1916 to 1921, inclusive.

Because of the comparatively short period for which data are available, no conclusions can be safely drawn from the results shown in Table 8. Of the five methods included in this experiment burning all of the straw produced slightly the highest average yields in the 6-year period.

The deficiency of humus in the dry-farm soils of the Columbia River and Great Basin regions suggests the advisability of turning

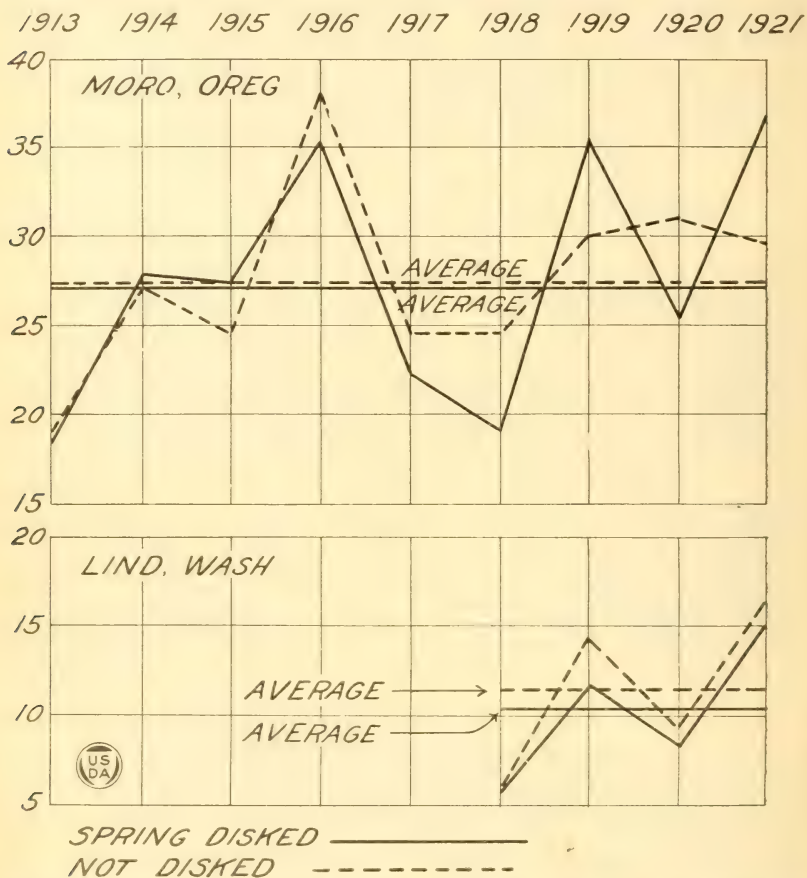


FIG. 12. Annual and average acre yields, in bushels, of winter wheat in varying numbers of years at Moro, Oreg., and Lind, Wash., when grown after summer fallow for which the ground had been plowed in late spring with the stubble disked or not disked in early spring before plowing.

under the stubble and straw in preference to burning them. Stubble and straw decay very slowly in these soils, however, and when turned under in too large quantities occasionally may produce an unfavorable soil condition by inducing excessive drying or by producing an incorrect balance between the nitrates and moisture supply, thereby causing a rank growth of straw, which may induce drought injury and reduce grain yields.

TABLE 8.—Annual and average yields of Turkey winter wheat on ordinary fall-plowed fallow and on fallow with stubble variously treated, at Nephi, Utah, during the 6-year period from 1916 to 1921, inclusive.

Treatment.	Yield per acre (bushels).						
	1916	1917	1918	1919	1920	1921	Average.
Ordinary treatment, fall plowed	20.0	23.6	17.4	21.9	25.5	38.9	24.5
All straw plowed under	11.1	22.7	20.2	20.7	28.7	39.2	23.8
All straw burned on plat	12.6	24.4	20.5	21.7	29.0	40.8	24.8
Grain headed high:							
Stubble plowed under	10.8	25.6	18.2	23.4	27.6	40.9	24.4
Stubble burned	10.9	26.1	17.1	25.3	26.1	42.7	24.7

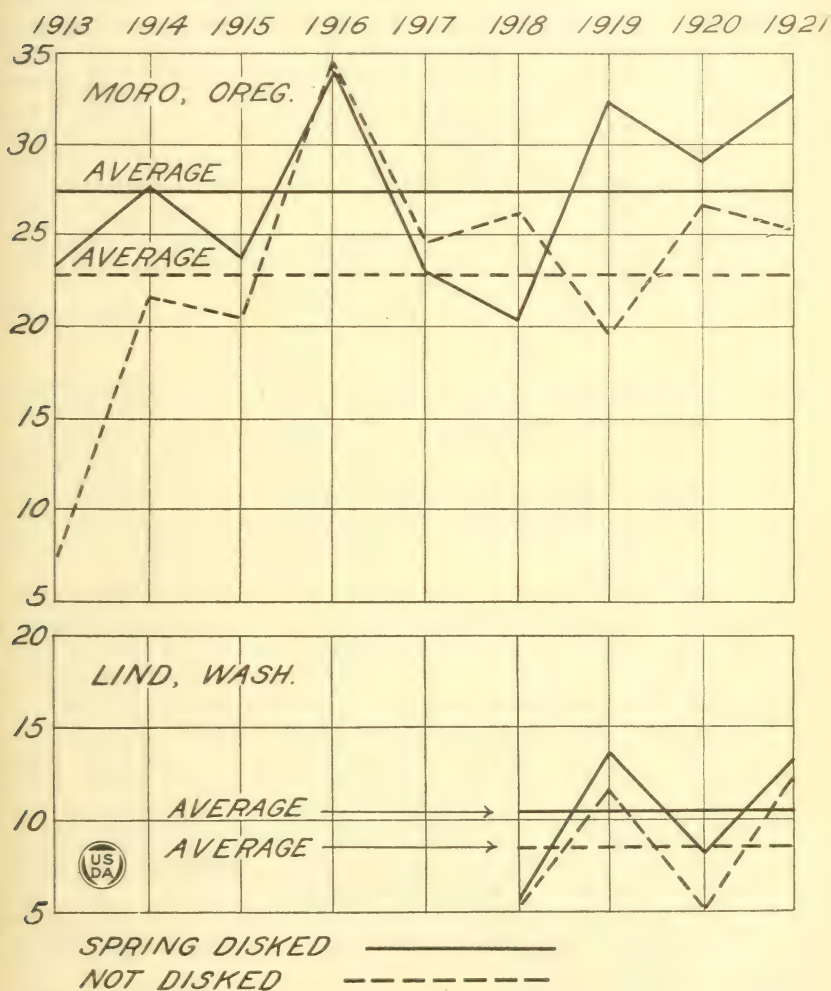


FIG. 13.—Annual and average acre yields, in bushels, of winter wheat in varying numbers of years at Moro, Oreg., and Lind, Wash., when grown after summer fallow for which the ground had been plowed in early summer with the stubble disked or not disked in early spring before plowing.

PLOWING.

Of all tillage operations plowing is considered the most important and necessary. Very little experimental work has been done in attempting to find out whether any other cultural operation, such as disking, will take the place of plowing. For very light soils, a disking sufficiently thorough to keep the ground free from weeds occasionally may take the place of plowing, but no implement yet invented is as valuable as the plow for killing weeds and preparing an ideal seed bed.

Of the controllable factors influencing yields of winter wheat, the time of plowing has been found to be one of the most important. Time of plowing also is of much importance to the dry farmer in the distribution of labor. Plowing for summer fallow may be done in the fall at any time after harvest until the ground freezes or at any time in the spring after the soil is dry enough. In many sections of eastern Oregon and Washington the harvesting of wheat is completed by August 15, while the ground does not often freeze before December 1. This allows a considerable period for fall plowing, both before and after the time for sowing winter wheat. Spring plowing, however, is generally practiced by farmers in the Columbia River and Great Basin areas.

Experiments to determine the best time to plow as well as the best manner of plowing were carried on at each of the three stations, and the results are presented in this bulletin. 

PLAN OF THE EXPERIMENTS AT MORO.

In the experiments to determine the best date for spring plowing at Moro 60 tenth-acre plats were used, 30 being in crop and 30 in fallow each year. Of these plats 2 out of every 10 were check plats. One series of 10 plats was plowed on April 1, one on May 1, and one on June 1, except that the check plats in each series were plowed on April 1. Different methods of cultivating the summer fallow were employed on each of the plats in a series, except that all check plats were treated alike.

For the fall-plowing experiments, 40 tenth-acre plats were used, 20 being in crop and 20 left fallow each year. Eight plats were plowed early in the fall, when the ground was dry, 4 with a disk plow and 4 with a moldboard plow. Eight plats were plowed late in the fall, when the ground was wet, 4 with a disk and 4 with a moldboard plow. Beginning in the fall of 1919 all fall plowing was done with a moldboard plow. Two plats out of every 10 were check plats uniformly cultivated. During the first 5 years these were plowed late in the fall with a moldboard plow, but since then they have been plowed on April 1 with a moldboard plow, so as to have them uniform with the check plats in the experiments to determine the best date to plow in the spring.

In all the date-of-plowing experiments Turkey winter wheat was used. The depth of plowing was from 7 to 8 inches in both spring and fall plowing.

Depth-of-plowing experiments also have been conducted at Moro since 1912. In these experiments 40 tenth-acre plats were used, 20 being cropped and 20 left fallow each year. One series of 10 plats was plowed from 8 to 10 inches deep and one series from 4 to 5 inches

deep each year. Pacific Bluestem spring wheat was used until 1917; in 1918 and 1919 Baart spring wheat was used; and in 1920 and 1921 Turkey winter wheat was used. In each series two check plats were plowed 8 to 10 inches deep, uniformly cultivated, and cropped to spring wheat from 1912 to 1919, inclusive, and to winter wheat in 1920 and 1921.

The plats of the tillage experiments were arranged in series of 10, with the third and eighth plats in each series used as uniformly cultivated check plats. The dimensions of the plats were 2 rods by 8 rods. Each series or block was surrounded by a road 16 feet wide, and the plats were divided by alleys 5 feet wide. In the spring-plowing experiments the check plats were all plowed in April and given uniform cultural treatment thereafter. In the fall-plowing experiments the check plats were plowed late in the fall during the first five years, but during the past three years they were plowed in the spring to make them uniform with the other check plats.

YIELDS OF CHECK PLATS AT MORO.

The average yields of the check plats in the date-of-plowing experiments at Moro are shown in Table 9. The yields from the check plats are average yields of two plats in each year. Average yields are shown in the table for the entire 9-year period from 1913 to 1921, inclusive; for the years 1914 to 1921, inclusive; and for 1919 to 1921, inclusive. The yields of the check plats will be taken into consideration in interpreting the results obtained in the tillage experiments at Moro.

TABLE 9.—Average yields of Turkey winter wheat on the uniformly cultivated check plats in the tillage experiments at Moro, Oreg., by periods in all or part of the 9-year period from 1913 to 1921, inclusive.

Series.	Average yield per acre (bushels).		
	1913 to 1921.	1914 to 1921.	1919 to 1921.
April plowing.....	30.6	31.2	35.1
May plowing.....	30.9	31.9	36.3
June plowing.....	29.0	29.5	35.6
Early fall plowing (dry).....		31.8	38.3
Late fall plowing (wet).....		28.4	35.1

DATE-OF-PLOWING EXPERIMENTS.

RESULTS AT MORO.

The yields obtained in the date-of-plowing experiments in the years 1913 to 1921, inclusive, are shown in Table 10 for various methods of cultivating the summer fallow. For the spring plowing the yields are from single tenth-acre plats. In the fall-plowing experiments the yields are averages of duplicate tenth-acre plats for each year. For each date of plowing eight tenth-acre plats were used in addition to the check plats. Results are available in the spring-plowing experiments for the nine years from 1913 to 1921, inclusive, and in the fall-plowing experiments for the eight years from 1914 to 1921, inclusive. Data from these experiments are shown graphically in Figures 14 and 15.

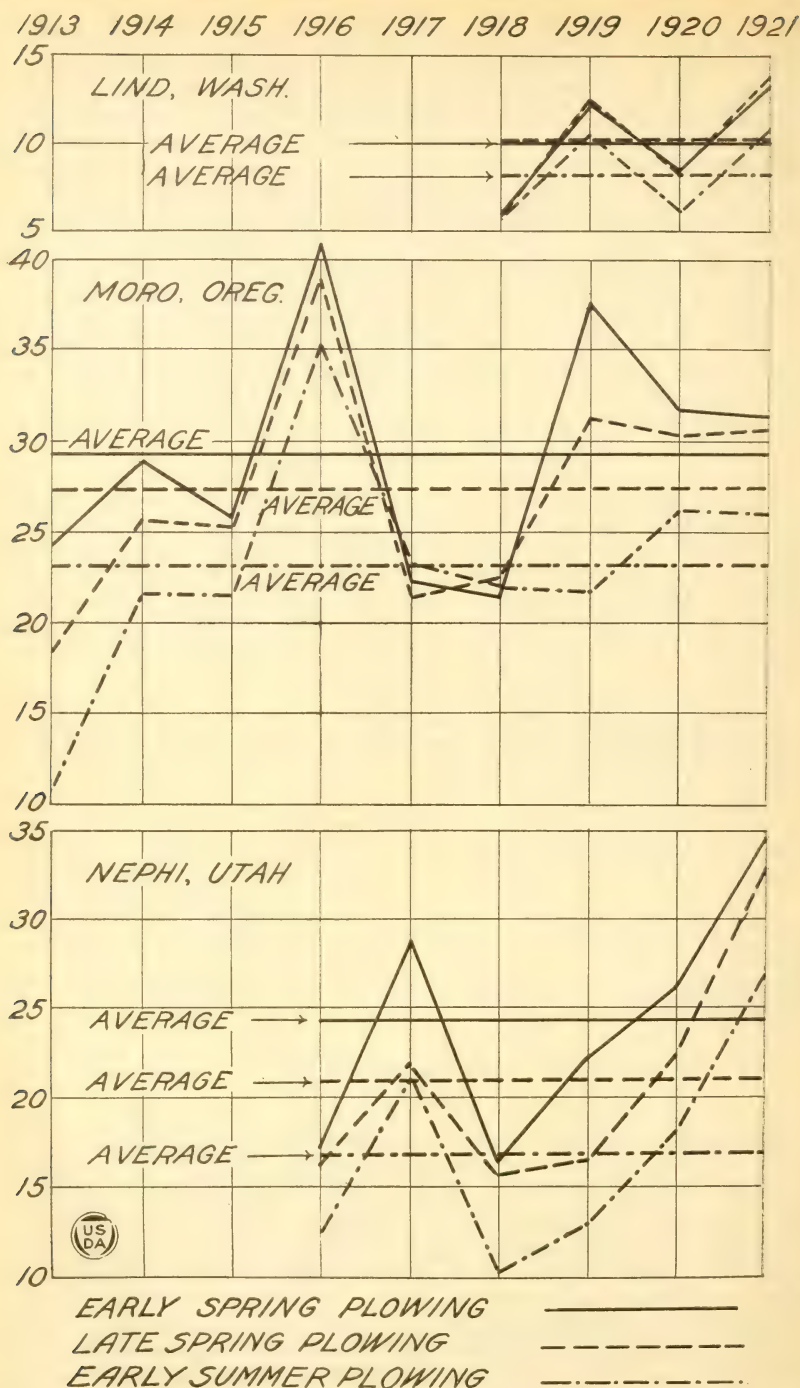


FIG. 14.—Annual and average acre yields, in bushels, of winter wheat in varying numbers of years at Moro, Oreg., Lind, Wash., and Nephi, Utah, when grown after summer fallow for which the land had been plowed in early spring, late spring, and early summer, respectively.

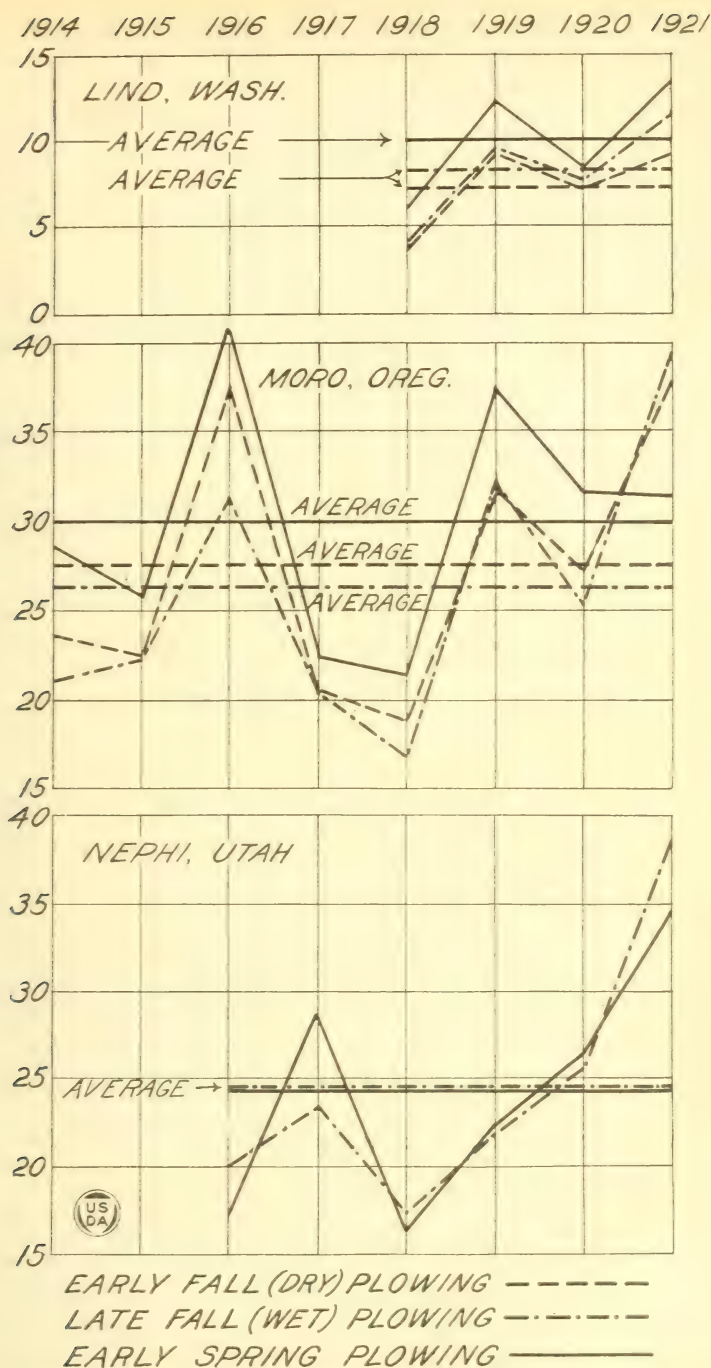


FIG. 15.—Annual and average acre yields, in bushels, of winter wheat in varying numbers of years at Moro, Oreg., and Lind, Wash., when grown after summer fallow for which the land had been plowed early in the fall (dry), late in the fall (wet), and early in the spring, respectively.

Table 11 summarizes the data given in Table 10 and in addition shows the yields of winter wheat obtained in the years from 1914 to 1919, inclusive, after summer fallow plowed in the fall with a disk plow and with a moldboard plow. The use of the disk plow was discontinued after 1919. In Table 11 the annual yields from the fall-plowed plats are from four tenth-acre plats each year except for the years 1920 and 1921. For these two years the yields are averages of eight tenth-acre plats each year.

The methods of cultivation used on each of the 10 plats in the experiments reported in Table 10 were as follows:

1. Frequent cultivation; disked in both fall and spring before plowing; clean summer fallow.
2. No cultivation of summer fallow after plowing; weeds hoed off before maturity;
- 3 and 8. Check plats. Frequent cultivation; disked in the spring before plowing. clean fallow.
4. One harrowing immediately after plowing; no further cultivation; weeds hoed off before maturity.
5. Frequent cultivation; no disking before plowing; clean cultivation of fallow.
6. Frequent cultivation; same as No. 5 except that the crop was harrowed in spring.
7. Packed with subsurface packer after plowing and harrowed once only; weeds hoed off before maturity.
9. Packed with subsurface packer and frequently cultivated; clean summer fallow.
10. Packed with surface packer and frequently cultivated; clean summer fallow.

TABLE 10.—*Annual and average yields of Turkey winter wheat in tillage experiments at Moro, Oreg., during the 9-year period from 1913 to 1921, inclusive.*

[Yields of check plats, all of which were plowed on April 1, are not included in the averages.]

Method of cultivating fallow.	Yields per acre (bushels).										Average.	
	1913	1914	1915	1916	1917	1918	1919	1920	1921		Nine years, 1913 to 1921.	Eight years, 1914 to 1921.
<i>Plowed April 1 (early spring).</i>												
Treatment 1.....	23.0	25.6	23.6	34.3	21.2	17.3	38.3	25.0	36.5	27.2	27.7	27.2
Treatment 2.....	22.3	26.0	22.1	33.2	24.0	21.0	36.2	27.0	27.7	26.6	27.2	27.2
Treatment 3 (check)...	25.1	26.9	26.3	41.3	25.0	22.3	38.5	29.7	31.3	29.6	30.2	30.2
Treatment 4.....	27.1	29.3	24.8	39.8	19.8	19.5	31.2	27.7	25.8	27.2	27.2	27.2
Treatment 5.....	30.0	32.0	26.4	45.7	25.7	23.5	39.7	32.8	31.7	31.9	32.1	32.1
Treatment 6.....	23.7	30.5	27.5	37.8	22.0	20.3	41.2	35.0	32.8	30.1	30.9	30.9
Treatment 7.....	27.2	31.0	25.8	44.1	14.7	18.3	36.0	33.3	25.7	28.5	28.6	28.6
Treatment 8 (check)...	26.3	28.3	27.9	45.7	23.5	21.7	40.2	37.3	34.2	31.7	32.3	32.3
Treatment 9.....	23.1	28.5	28.1	42.7	25.7	22.8	39.2	34.5	35.7	31.1	32.2	32.2
Treatment 10.....	18.0	28.0	28.7	49.3	25.1	27.8	38.5	38.3	35.8	32.2	33.9	33.9
Average.....	24.3	28.9	25.9	40.9	22.3	21.3	37.5	31.7	31.5	29.4	30.0	30.0
<i>Plowed May 1 (late spring).</i>												
Treatment 1.....	18.5	27.8	27.5	35.1	22.3	19.2	35.3	25.3	36.7	27.5	28.7	28.7
Treatment 2.....	20.5	25.0	22.7	33.2	23.2	22.3	28.5	28.3	29.8	25.9	26.6	26.6
Treatment 3 (check)...	23.6	27.4	27.0	38.2	24.3	22.0	37.2	28.3	35.8	29.3	30.0	30.0
Treatment 4.....	19.8	28.0	25.1	36.7	19.0	23.5	30.3	27.7	26.0	26.2	27.0	27.0
Treatment 5.....	19.0	27.0	24.7	38.0	24.7	19.7	30.0	31.0	29.8	27.7	28.7	28.7
Treatment 6.....	16.0	26.3	25.5	40.2	20.3	19.5	31.8	31.5	30.3	26.8	28.2	28.2
Treatment 7.....	18.3	27.7	25.5	35.8	10.3	24.1	30.5	32.3	28.8	25.9	26.9	26.9
Treatment 8 (check)...	21.8	28.2	30.0	46.3	25.4	23.5	42.5	38.5	36.0	32.5	33.8	33.8
Treatment 9.....	17.7	23.4	26.4	42.8	25.4	24.0	32.8	31.8	31.2	28.4	29.7	29.7
Treatment 10.....	18.1	20.8	24.6	48.0	25.8	22.7	30.7	35.0	31.8	28.6	29.9	29.9
Average.....	18.5	25.8	25.2	38.7	21.4	22.5	31.2	30.3	30.6	27.1	28.2	28.2

TABLE 10.—Annual and average yields of Turkey winter wheat in tillage experiments at Moro, Oreg., during the 8-year period from 1913 to 1921, inclusive—Continued.

[Yields of check plots, all of which were plowed on April 1, are not included in the averages.]

Method of cultivating fallow.	Yields per acre (bushels).										Average.	
	1913	1914	1915	1916	1917	1918	1919	1920	1921		Nine years, 1913 to 1921.	Eight years, 1914 to 1921.
<i>Plowed June 1 (early summer).</i>												
Treatment 1.....	22.0	27.7	23.0	24.3	23.1	20.3	22.7	23.0	22.5	27.4	27.4	27.4
Treatment 2.....	7.4	22.1	21.5	36.2	24.8	23.0	19.8	24.2	23.0	22.4	22.4	24.3
Treatment 3 (check).....	23.0	25.7	26.5	32.0	25.0	21.2	35.8	27.7	37.5	28.3	28.3	28.9
Treatment 4.....	7.2	24.0	21.3	33.8	22.5	22.7	19.8	25.0	24.0	22.6	22.6	24.5
Treatment 5.....	7.3	21.6	20.5	34.8	24.7	26.0	19.5	26.5	25.2	22.9	22.9	24.9
Treatment 6.....	10.8	21.3	21.5	35.3	20.8	18.2	23.0	26.0	27.3	22.8	22.8	24.3
Treatment 7.....	6.5	18.5	20.8	34.2	20.6	26.1	19.8	28.5	27.1	22.5	22.5	24.4
Treatment 8 (check).....	26.0	27.2	25.0	22.0	23.3	20.2	27.8	37.0	38.2	29.6	29.6	30.1
Treatment 9.....	10.5	19.0	19.5	32.3	24.3	20.0	21.3	23.5	24.7	21.7	21.7	23.1
Treatment 10.....	11.6	13.8	23.1	32.2	24.3	13.1	13.3	26.3	24.2	22.4	22.4	23.7
Average.....	10.6	21.5	21.4	35.1	23.1	22.0	21.8	26.1	26.0	23.1	23.1	24.6
<i>Plowed in early fall (dry).</i>												
Treatment 1.....		23.5	25.5	34.7	20.0	18.3	30.5	28.6	39.6			27.6
Treatment 2 (check).....		25.9	24.6	42.7	21.4	24.4	28.2	22.9	42.8			31.8
Treatment 4.....		22.9	18.1	35.3	20.7	18.0	28.8	20.6	34.5			24.9
Treatment 5.....		24.1	24.4	42.9	21.3	21.3	32.4	30.7	38.8			29.5
Treatment 6.....		24.4	22.6	36.8	20.5	17.9	35.7	28.6	38.4			28.1
Average.....		23.7	22.6	37.6	20.6	18.9	31.9	27.1	37.8			27.5
<i>Plowed in late fall (wet).</i>												
Treatment 1.....		21.2	23.9	30.5	20.6	16.6	31.7	26.6	40.6			26.5
Treatment 2 (check).....		25.0	21.8	32.1	21.3	21.5	35.8	26.4	40.1			28.4
Treatment 4.....		19.5	22.0	34.6	18.2	16.6	32.8	25.7	40.0			26.2
Treatment 5.....		22.8	21.4	31.2	21.8	18.3	31.9	25.2	37.7			26.3
Treatment 6.....		21.2	22.5	28.6	20.6	15.7	32.8	23.7	38.7			25.5
Average.....		21.2	22.5	31.2	20.3	16.8	32.3	25.3	39.2			26.1

TABLE 11.—Annual and average yields of Turkey winter wheat on fallow land plowed on different dates at Moro, Oreg., during the 8-year period from 1914 to 1921, inclusive.

Method and date of plowing.	Yields per acre (bushels).								
	1914	1915	1916	1917	1918	1919	1920	1921	Average.
Fall plowing:									
Disk plow—									
Early (dry).....	23.3	22.3	33.9	19.0	17.6	30.9	-----	-----	24.8
Late (wet).....	21.0	23.2	30.4	20.2	16.3	31.3	-----	-----	23.7
Moldboard plow—									
Early (dry).....	24.1	22.8	41.0	22.2	20.1	32.8	27.1	37.8	28.5
Late (wet).....	21.3	21.6	32.1	20.3	17.2	33.2	25.3	39.2	26.3
Spring plowing:									
Plowed April 1 (early).....	28.9	25.9	40.9	22.3	21.3	37.5	30.7	31.5	30.6
Plowed May 1 (late).....	25.8	25.2	38.7	21.4	22.5	31.2	33.3	30.6	28.2
Summer plowing:									
Plowed June 1 (early).....	21.5	21.4	35.1	23.1	22.0	21.8	26.1	26.0	24.6

Table 11 shows that the highest average yield of winter wheat was obtained from plowing for summer fallow on April 1 and the second highest average yield from plowing early in the fall with the moldboard plow. The lowest average yields were obtained from the late fall and early summer plowing.

In the years 1914 to 1919, inclusive, when two types of plows were used for the fall-plowing experiments, the average yields obtained were as follows:

Disk plow, early (dry).....	24.8 bushels per acre.
Disk plow, late (wet).....	23.7 bushels per acre.
Moldboard plow, early (dry).....	27.2 bushels per acre.
Moldboard plow, late (wet).....	24.3 bushels per acre.

These results indicate that for early fall plowing the moldboard plow was the better type. However, in considering the yields of the check plats it appears that the ground on which was located the series of plats plowed early in the fall with the moldboard plow was considerably better than that on which was located the series plowed late in the fall. The average yield obtained from the early fall plowing, therefore, undoubtedly is higher than it should be when compared with those for the other dates of plowing.

The physical texture of the soil at Moro is such that when plowed dry in the fall with a moldboard plow it turns up in large lumps, so that the ground is left very rough during the winter. This is not true of the late fall plowing, which is done after the autumn rains have penetrated the soil sufficiently to make the ground plow easily and well. The disk plow, even when the ground is plowed dry, has a tendency to leave the surface finer and more even after plowing. The draft, of course, is much greater when the ground is plowed dry than when plowed wet.

The average yields obtained from the April plowing were significantly higher than those obtained from either the May or the June plowing. The check-plat yields indicate that the productivity of the soil of the June-plowed series was not quite so great as that of the April-plowed and May-plowed series, but, notwithstanding this, the yields obtained from the April-plowed series were significantly higher, especially when the fact is considered that they represent the average yields of 8 tenth-acre plats each year.

The average acre yield of the April-plowed series in the 9-year period was 6.3 bushels per acre more than the average yield of the June-plowed series and 2.3 bushels more than the average yields of the May-plowed series. The 9-year average yield of the plats of the May-plowed series was 4 bushels more than that of the June-plowed series.

In the nine years for which results are available the yield from the June-plowed series slightly exceeded the average yield of the April-plowed series in two years, 1917 and 1918. In fact, during these two years the average yields of the series of plats plowed in all three months varied but little. For the years 1913 and 1919, on the other hand, the average yield of the April-plowed series was nearly twice that of the June-plowed series.

The yields obtained from the plats plowed in the fall for summer fallow were consistently lower than the yields obtained from the plats plowed early in the spring, except in the case of the early fall plowing

with the moldboard plow. The 8-year average yields obtained from the plats plowed early (dry) in the fall were 2.5 bushels less than those obtained from the plats plowed on April 1 and 0.7 bushel less than the yield from the plats plowed on May 1. The yields obtained from the late (wet) fall plowing were 2.1 bushels less per acre than those obtained from the plats plowed on May 1, and 1.5 bushels more per acre than the yield of the plats plowed on June 1.

RESULTS AT LIND.

The summer-fallow experiments at Lind were conducted on two series of twentieth-acre plats, one series being in fallow and one in crop each year. These series of plats are widely separated, being on opposite sides of the station farm. Check plats were not used, and because the experiments were somewhat extensive and in their present form were considered somewhat temporary they have not been replicated each season.

In the Washington portion of the Columbia Basin the greater part of the fallow is plowed in the spring, only a very little being plowed in the fall. Two dates of fall plowing, two of spring plowing, and one of early summer plowing are included in these experiments. The two fall dates represent dry and wet plowing and the three spring and summer dates early, intermediate, and late work, the first being done at a time when the soil is wettest, the third when the soil is practically dry, and the second intermediate between the other two. All of these dates vary with the season and are considered as more or less relative, depending on prevailing conditions during any one year. Experiments to determine the best date of plowing have been combined with those covering other factors as well, and the yields given for dates of plowing are the averages obtained from 3 to 12 plats plowed on each date in each year. The data are presented in Table 12 and are shown graphically in Figures 14 and 15.

TABLE 12.—*Annual and average yields of wheat on fallow land plowed on different dates, at Lind, Wash., during the 4-year period 1918 to 1921, inclusive.*

Time of plowing and condition of soil.	Annual and average yields per acre (bushels).				
	1918	1919	1920	1921	4-year average.
Fall plowing:					
Dry ¹	3.9	9.2	7.0	8.9	7.2
Wet ¹	4.1	9.6	7.5	11.7	8.2
Spring plowing:					
March (early) ²	6.0	12.3	8.4	13.4	10.0
April (late) ³	5.9	12.6	8.3	13.8	10.1
Summer plowing:					
June (early) ⁴	5.8	10.3	6.0	10.8	8.2

¹ Average of 3 plats variously cultivated.
² Average of 12 plats variously cultivated.

³ Average of 7 plats variously cultivated.
⁴ Average of 6 plats variously cultivated.

☞ In planning the experiments it was intended to crop entirely to winter wheat, but seasonal conditions prevented adherence to this plan. The crops of 1918, 1920, and 1921 were Early Baart spring wheat, and the crop of 1919 was Turkey winter wheat. This variation, however, apparently did not affect the results.

The variations in yield for the different dates of plowing given in Table 12 are not large and perhaps are too small to serve as a basis for conclusions. The percentage variations, however, are comparable with those found under the more favorable conditions at the other two stations, results from which are reported in this bulletin. These data show what may be expected where moisture is an extreme limiting factor in production.

The time and method of tillage are determined by local conditions, and in the drier portions of the Columbia Basin fall plowing, either wet or dry, is not good practice. The data given in Table 12 are in full agreement with farm experience in this respect.

Of the experiments in spring plowing, the results from the first two dates are practically identical, the yields being higher than those obtained from the late or summer plowing. During the spring, before volunteer grain and weeds grow freely, there is no advantage from a moisture standpoint in stirring the soil. Moisture studies show that before this time, which during the period of these experiments corresponded approximately to the date of the April plowing, nothing was gained in moisture content by plowing and that moisture content was equal in the plats plowed in March and April. Therefore the yields are equal. After this time the drain on soil moisture from plant growth becomes heavy enough, unless checked by tillage, to reduce materially the total moisture in the soil, and the yields from the plats plowed in June consequently are lower.

RESULTS AT NEPHI.

Date-of-plowing experiments were conducted at Nephi during the 6-year period, 1916 to 1921, inclusive.

The time that spring plowing can be started on the dry farms near Nephi is rather indefinite, because of the variability of the seasons. This operation can begin as early as April 1 in some years, but in others not until May 1, and occasionally it is delayed still later. Because of this fact, no definite dates were set for plowing the various plats, but different stages of growth of volunteer wheat were used instead. The first plowing is done just as soon as the plow will scour; the second, when the volunteer growth is 6 inches high; the third, when the wheat is 12 inches high; the fourth, when the volunteer crop is in early bloom; and the fifth, when the wheat kernel is in the milk stage. For fall plowing the land is turned over at a medium early date, near October 10. The depth of plowing usually is 8 inches.

The experiments were conducted on duplicate tenth-acre plats 36 by 121 feet. The results are shown in Table 13 and graphically in Figures 14 and 15.

The results shown in Table 13 indicate a very decided advantage in favor of early spring plowing as compared with plowing at later dates. The yield decreases regularly with the later plowing. The difference between fall plowing and spring plowing in this test was very slightly in favor of fall plowing.

A large part of the plowing on the dry lands in the Great Basin is left until spring. Spring plowing in this section usually is cheaper than fall plowing, because less power is needed for the operation and because spring-plowed land does not require so much summer cultivation to check the growth of weeds and volunteer wheat.

TABLE 13.—*Annual and average yields of Turkey winter wheat, after full plowing and after spring plowing at different times, represented by different stages in the growth of volunteer wheat, at Nephi, Utah, during the 6-year period from 1916 to 1921, inclusive.*

Date of plowing.	Yield per acre (bushels).						
	1916	1917	1918	1919	1920	1921	Average.
Fall plowing:							
About October 10.....	20.0	23.6	17.4	21.9	25.5	38.9	24.5
Spring plowing:							
Early.....	17.1	28.8	16.3	22.1	26.2	34.7	24.2
When volunteer wheat was 6 inches high.....	16.1	21.9	15.6	16.5	22.2	32.9	20.9
When volunteer wheat was 12 inches high.....	15.6	22.6	15.7	17.6	19.0	30.4	20.2
When plants were in early bloom.....	12.6	21.0	10.1	12.9	18.1	26.8	16.9
When kernels were in milk stage.....	9.9	21.7	9.7	5.5	18.1	27.7	15.5

These two factors should be considered, but economy of production is of first importance. Usually the time between the first possible opportunity for spring plowing and the time the volunteer wheat is 6 inches high is not more than two weeks, and sometimes less. With a large acreage left for spring plowing, a good part of the land cannot be plowed before the volunteer wheat is 6 inches high, and it is not uncommon to see plowing done in summer when the wheat plants are in the milk stage, the last stage covered by the experiment. That it pays to work the land as early as possible in the spring is clearly indicated from the results shown in the table.

In another experiment, reported later, to determine the influence on yield of different methods of handling summer fallow, a direct comparison was also obtained between the yields of winter wheat on ground plowed for fallow in the spring and in the fall. Yields are available for spring-plowed and fall-plowed fallow given ordinary cultivation during the years from 1910 to 1921, inclusive, and for spring-plowed and fall-plowed fallow given no cultivation and weeds hoed during the years from 1916 to 1921, inclusive. These data, together with the data for the fall plowing and spring plowing in the experiment listed in Table 13, are shown in Table 14.

TABLE 14.—Annual and average yields of Turkey winter wheat grown on tenth-acre plots plowed in the fall and in the spring with fallow treated in various ways, at Nephi, Utah, during the 12-year period from 1910 to 1921, inclusive.

[illegible]

As is shown in Table 14 the average yield for the tenth-acre plats plowed in the spring and in the fall for the 12-year period from 1910 to 1921, inclusive, were practically identical. In the other comparisons between spring plowing and fall plowing the average yields were slightly in favor of the fall plowing. The average yield from the spring-plowed land in the three experiments for the 6-year period from 1916 to 1921, inclusive, was 25.2 bushels and the average yield from the fall-plowed land during the same period was 25.5 bushels per acre, a difference of 0.3 bushels per acre in favor of fall plowing for summer fallow at Nephi.

Using these results as a basis of judgment, it might be stated that dry farmers in the Great Basin area should plow part of their land to be summer fallowed in the fall, and if any is left for spring plowing it should be only such an acreage as can be plowed within the first few weeks of spring.

DEPTH-OF-PLOWING EXPERIMENTS.

Experiments to determine what effect depth of plowing may have on the yields of wheat grown after summer fallow were conducted at Moro, Lind, and Nephi. At Moro spring wheat was grown on land plowed early in April, both 5 and 10 inches deep. At Nephi winter wheat was grown on land plowed 5 and 10 inches deep in the fall, subsoiled 15 to 18 inches deep, plowed 8 inches deep in the fall and 3 inches deep in the spring, plowed 3 inches deep in the fall and 8 inches deep in the spring, and plowed 8 inches deep in both fall and spring. At Lind wheat was grown on land plowed 4 and 6 inches deep on two dates, September 1 and November 1, and on land plowed 4 and 8 inches deep on three dates, March 1, April 1, and June 1.

RESULTS AT MORO.

In the depth-of-plowing experiments at Moro 40 tenth-acre plats were used, 20 being in crop and 20 in fallow each year. Plats 3 and 8 in each series of 10 are check plats uniformly cultivated, all being plowed 8 to 9 inches deep and the fallow kept clean. Table 15 shows the yields of each plat in these experiments in the years 1912 and 1914 to 1921, inclusive, no results being available for the year 1913. Certain of these yields are shown graphically in Figure 16.

Table 15 shows that there was considerable variation in the average yield of the individual check plats in each series. The check plats (No. 3) which were located in the west end of each series gave lower average yields than the check plats (No. 8) which were located in the east end of each series. The average yield of the two check plats in the shallow-plowed series was 21.5 bushels, and the average yield of the two check plats in the deep-plowed series was 21.6 bushels per acre, indicating that the productivity of the soil of the two series was practically the same. The average yield, therefore, of the eight plats plowed shallow and of the eight plowed deep should be comparable.

The 9-year average yield of the eight tenth-acre plats plowed 5 inches deep (Table 15) was 20.4 bushels per acre, and the average yield of the eight plats plowed 10 inches deep in the same period was 21.3 bushels per acre, an increase of 0.9 bushel in favor of the deep plowing.

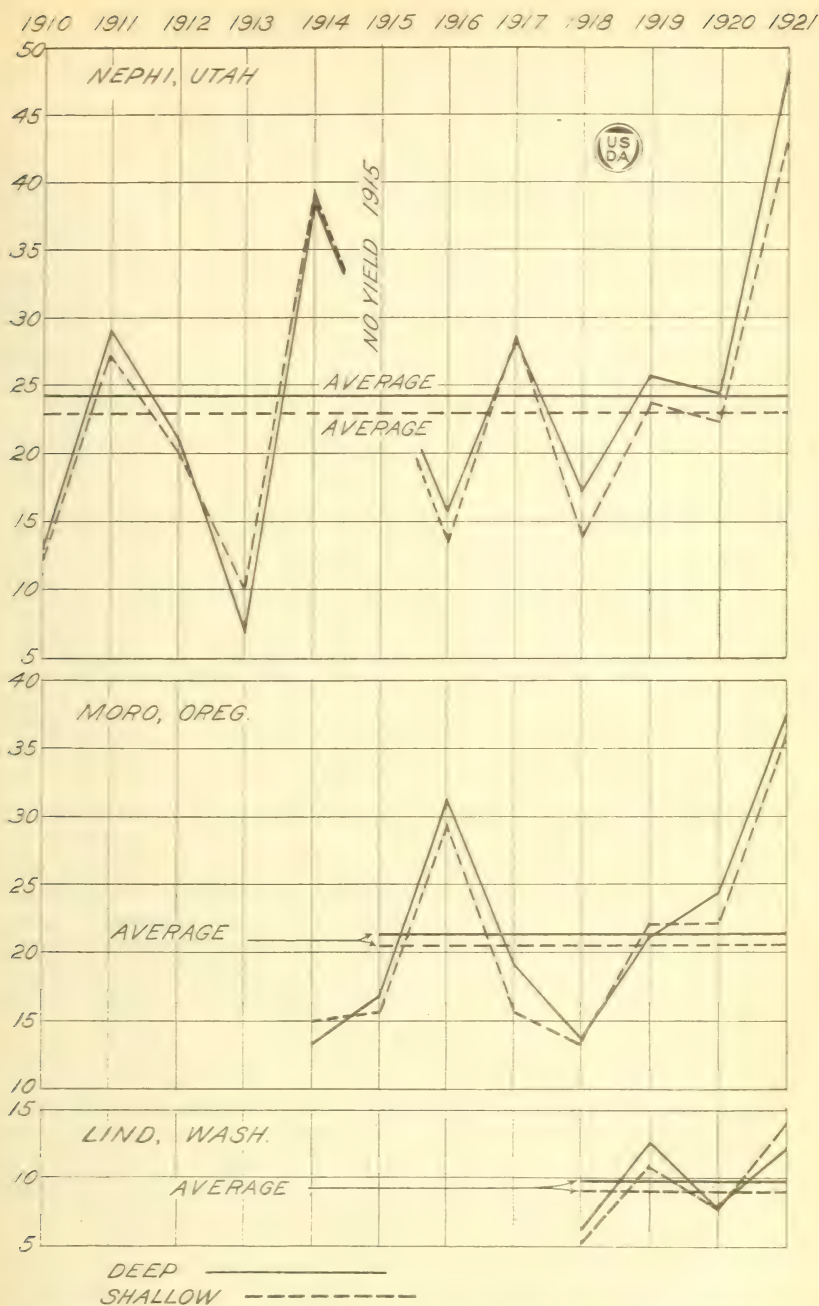


FIG. 16.—Annual and average acre yields, in bushels, of winter and spring wheats in varying numbers of years at Moro, Oreg., of spring wheat at Lind, Wash., and of winter wheat at Nephi, Utah, when grown after summer fallow for which the land had been plowed deep (10 inches) and shallow (5 inches).

TABLE 15.—*Annual and average yields of wheat in the depth-of-plowing experiments at Moro, Oreg., in the years 1912 and 1914 to 1921, inclusive.*

[Pacific Bluestem spring wheat was grown in 1912 and from 1914 to 1917, inclusive; Early Baart spring wheat in 1918 and 1919; and Turkey winter wheat in 1920 and 1921.]

Cultivation method.	Plat.	Annual and average yields per acre (bushels).									
		1912	1914	1915	1916	1917	1918	1919	1920	1921	9-year average.
Shallow spring plowing.....	No. 1...	13.6	14.6	13.6	28.7	16.0	14.2	22.6	23.3	31.2	19.8
	No. 2...	13.6	13.9	16.8	26.7	18.2	13.2	20.1	18.7	35.5	19.6
	No. 4...	14.5	13.9	17.5	26.0	9.8	12.7	23.5	18.7	38.5	19.5
	No. 5...	15.0	13.5	17.5	28.3	20.3	12.0	20.5	21.3	37.3	20.6
	No. 6...	12.9	15.5	17.0	28.5	18.3	14.3	21.6	21.8	37.5	20.8
	No. 7...	16.6	17.3	9.6	31.7	8.7	14.2	25.1	18.5	36.7	19.8
	No. 9...	15.1	14.5	16.6	32.2	16.7	12.5	21.6	26.2	35.5	21.2
	No. 10...	18.0	17.0	16.3	33.0	19.0	13.5	21.2	27.3	34.3	22.2
	Average.....	14.9	15.0	15.6	29.4	15.9	13.3	22.0	22.0	35.8	20.4
Deep spring plowing.....	No. 1...	12.8	9.0	14.8	27.2	19.3	9.5	20.8	14.8	36.5	18.3
	No. 2...	14.4	8.0	17.5	25.0	19.7	10.2	22.5	18.7	45.5	20.2
	No. 4...	15.3	12.0	19.0	30.0	18.2	12.2	20.8	22.8	34.7	20.6
	No. 5...	13.9	14.0	16.3	31.0	18.2	13.0	20.8	26.2	33.0	20.7
	No. 6...	13.4	14.3	17.0	30.3	20.0	15.5	20.2	27.1	36.5	21.6
	No. 7...	16.1	15.5	16.8	32.5	17.0	14.7	18.5	20.0	34.7	20.6
	No. 9...	18.0	17.1	16.6	36.7	18.3	15.0	21.8	32.3	37.2	23.7
	No. 10...	17.8	16.3	16.1	36.3	22.0	17.0	23.3	34.5	40.8	24.9
	Average.....	15.2	13.3	16.8	31.1	19.1	13.4	21.1	24.5	37.4	21.3
Checks, shallow series.....	No. 3...	13.3	13.0	16.0	28.2	17.3	13.2	24.7	20.5	39.0	20.6
	No. 8...	13.0	16.5	18.1	32.3	15.6	15.2	22.5	28.7	40.7	22.5
Checks, deep series.....	No. 3...	15.0	12.0	15.3	27.8	19.3	10.5	20.0	19.0	42.0	20.1
	No. 8...	13.6	16.5	15.8	36.8	17.0	14.0	22.8	31.5	37.5	23.1
	Average.....										21.6

RESULTS AT LIND.

The depth-of-plowing experiments at Lind include variations in depth on all dates of fall plowing and spring plowing. Fall plowing of fallow is not generally practiced in the Columbia Basin, and therefore but two depths are used on the fall dates, as compared with three on each of the spring dates. These are more extensive experiments than those concerned with dates of plowing, and 26 plats were used exclusively for this purpose, 13 being in crop and 13 in fallow each year. The results are presented in Table 16 and in part are shown graphically in Figure 16.

Dry fall disking retards the absorption of soil moisture. From the data on comparative yield it is apparent, with the limited moisture supply and the soil type prevailing at Lind, that the fall plowing must have the same effect. It is further apparent that the detrimental effect must be greater as the depth of the layer of loose soil is increased, the more shallow plowing giving the best return in yield. It is logical to assume, therefore, that any tillage given to soil in a dry condition should be as shallow as possible.

The three spring and summer dates represent plowing under three different conditions of soil moisture and subsequent precipitation. The first represents plowing in a very moist soil with more or less subsequent rainfall; the second, plowing in a somewhat drier surface soil with less succeeding rainfall; and the third, plowing in dry soil with practically no subsequent rainfall.

TABLE 16.—*Annual and average yields of wheat in the depth-of-plowing experiments at Lind, Wash., during the 4-year period from 1918 to 1921, inclusive.*

Date and depth of plowing.	Annual and average yields per acre (bushels).				
	1918	1919	1920	1921	Average.
September 1 (dry):					
Depth 4 inches.....	3.8	9.3	7.2	9.7	7.5
Depth 6 inches.....	4.0	8.5	7.0	8.0	6.9
November 1 (wet):					
Depth 4 inches.....	4.2	10.5	7.9	11.7	8.6
Depth 6 inches.....	4.0	8.7	7.5	13.7	8.5
March (early spring):					
Depth 4 inches.....	5.2	10.7	7.8	14.0	9.4
Depth 6 inches.....	5.5	11.7	8.0	12.3	9.4
Depth 8 inches.....	6.2	12.7	7.9	12.3	9.8
April (late spring):					
Depth 4 inches.....	6.0	11.7	8.1	12.0	9.4
Depth 6 inches.....	5.7	11.3	6.8	12.5	9.1
Depth 8 inches.....	6.1	11.7	7.7	11.7	9.3
June (early summer):					
Depth 4 inches.....	5.8	10.0	6.2	11.0	8.2
Depth 6 inches.....	5.9	11.0	6.4	10.3	8.4
Depth 8 inches.....	6.3	9.3	6.2	10.3	8.0

On the early plowing, except in 1921, yields usually have increased with depth of plowing. This would tend to indicate that with better moisture conditions deep plowing is at least equal, if not superior, to shallow plowing. In the spring of 1920 the early plowing was delayed, and soil conditions at the date when it was actually done in reality corresponded to those at the usual midseason date, the results being similar. This delay was intentional in studying the influence of soil conditions on this factor. On the later dates nothing was gained by deeper plowing, indicating that under drier conditions and with the advance of the spring plowing season the average depth of plowing should be decreased.

RESULTS AT NEPHI.

The depth-of-plowing experiments at Nephi are divided into two parts. The purpose of the first section is to determine the effect of fall plowing to depths of 5 and 10 inches and subsoiling to depths of 15 and 18 inches on the yield of Turkey winter wheat. In subsoiling, a furrow was first made with a plow and the plow immediately followed by a subsoiler. Eight tenth-acre plats were used each year for these experiments, four being fallow and four producing a crop.

Fall-plowed land often must be plowed again in the spring to kill weeds and volunteer growth. The second section of the depth-of-plowing experiment was started in 1916 for the purpose of determining the proper depth of each, if both plowings were necessary. One plat was plowed 8 inches deep in the fall and 3 inches deep in the following spring; another was plowed 3 inches deep in the fall and 8 inches in the spring; and the third was plowed 8 inches deep in both fall and spring. Six tenth-acre plats were used in this test, half of which were fallow each year while the other half were in crop. The results of both experiments are included in Table 17 and part are shown graphically in Figure 16.

TABLE 17.—*Annual and average yields of Turkey winter wheat grown in tenth-acre plats in the depth-of-plowing experiments at Nephi, Utah, during the 12-year period from 1910 to 1921, inclusive.*

Treatment.	Annual and average yields per acre (bushels). ¹												
												Average.	
	1910	1911	1912	1913	1914	1916	1917	1918	1919	1920	1921	1910 to 1921	1916 to 1921
Subsoiled 18 inches deep.....	14.0	28.0	18.0	4.0	38.6	16.2	27.7	16.5	19.0	26.8	44.2	23.0	25.1
Subsoiled 15 inches deep.....	13.0	29.0	19.0	6.0	41.3	15.8	27.2	20.3	23.7	24.5	43.4	23.9	25.8
Plowed 10 inches deep.....	13.0	29.0	21.0	7.0	38.8	15.7	28.2	17.3	25.5	24.5	48.2	24.4	26.5
Plowed 5 inches deep.....	12.0	27.0	20.0	10.0	39.5	13.3	28.5	13.7	23.8	22.5	42.7	23.0	24.0
Plowed 8 inches in fall and 3 inches in spring.....						16.5	26.2	18.2	17.3	32.0	41.1	.....	25.2
Plowed 3 inches in fall and 8 inches in spring.....						14.5	28.2	14.3	15.5	28.0	38.7	.....	23.2
Plowed 8 inches in both fall and spring.....						15.7	26.8	15.8	17.0	27.5	38.4	.....	23.5

¹ No yields reported for 1915.

From the results in Table 17 it is evident that plowing beyond a depth of 10 inches is not necessary. In fact, when the labor costs of subsoiling are considered, this practice is decidedly unprofitable under conditions similar to those at Nephi. Between the 5-inch and 10-inch plowings there was an average difference of 1.4 bushels in favor of the greater depth for the period from 1910 to 1921 and an average difference of 2.5 bushels from 1916 to 1921. This indicates that fall plowing should be deeper than 5 inches.

In the second part of Table 17 the 8-inch fall plowing followed by plowing 3 inches deep the following spring gave a higher acre yield than either one of the two other methods. Taking all of the data presented in Table 17 into consideration, as well as other data given in this bulletin, it can be safely stated that one plowing either in fall or spring is sufficient if weeds can be controlled.

CULTIVATION OF SUMMER FALLOW.

PACKING AFTER PLOWING.

The use of surface and subsurface packers has been quite widely advocated, with the idea that they aid in conserving moisture and in increasing wheat yields. At present these implements are used by dry farmers in the West only to a limited extent.

Experiments to determine the effect of packing the soil on the yield of wheat grown after fallow have been conducted at Moro, Oreg., and at Lind, Wash. At Moro both the subsurface and the surface packer were used (Table 10) on land plowed April 1, May 1, and June 1 on which Turkey winter wheat was grown, and on early, deep and shallow spring plowing on which spring wheat was grown. At Lind the subsurface packer was used on ground plowed in March, April, and June.

RESULTS AT MORO.

Table 18 shows the average yields of winter and of spring wheat during the 9-year period from 1913 to 1921, inclusive, grown on summer-fallowed land not packed and packed with subsurface and surface packers. Both types of packers were used on five different methods of spring plowing, namely, land plowed early and late in the spring and in early summer and plowed shallow and deep in the spring. The subsurface packer also was used on two types of fallow treatments, clean fallow, or fallow frequently cultivated during the summer, and fallow that was harrowed once and given no further cultivation.

The average yields reported in Table 18 are from single tenth-acre plats each year. The yields of winter wheat from the April 1 plowing with clean fallow and the yields of spring wheat from the deep plowing with clean fallow are from adjacent plats. The other yields reported in Table 18 are from plats not adjacent. The detailed results are found in Table 10 and some of the data are shown graphically in Figures 17, 18, and 19.

TABLE 18.—Average yields of winter wheat grown at Moro, Oreg., after summer fallow plowed on three different dates and packed with surface and subsurface packers during the 9-year period from 1913 to 1921, inclusive, and of spring and winter wheat on shallow and deep plowing, clean fallowed and harrowed only once in the same period with 1913 omitted.

Time and depth of plowing and cultivation of fallow.	Yields per acre (bushels).		
	Not packed.	Subsurface packed.	Surface packed.
Date of plowing:			
April 1 (early spring)—			
Clean fallow.....	31.7	31.1	32.2
One harrowing.....	27.2	28.5	
May 1 (late spring)—			
Clean fallow.....	27.7	28.4	28.6
One harrowing.....	26.2	25.9	
June 1 (early summer)—			
Clean fallow.....	22.9	21.7	22.4
One harrowing.....	22.6	22.5	
Average.....	26.4	26.3	
Depth of plowing:			
Shallow—			
Clean fallow.....	20.6	21.2	22.2
One harrowing.....	19.5	19.8	
Deep—			
Clean fallow.....	21.6	23.7	24.9
One harrowing.....	20.6	20.6	
Average.....	20.5	21.3	

It will be noted from Table 18 that the average yield of Turkey winter wheat on the different dates of plowing and the methods of cultivating the summer fallow were practically identical for the plats not packed and those packed with the subsurface packer. There was a slight increase in yield from the surface-packed plats when compared with those not packed or those packed with the subsurface packer, but the increase was too slight in each case to be significant if the check-plat yields as reported in Table 10 are taken into consideration.

In the depth-of-plowing experiments in which spring wheat was used for seven years and winter wheat for two years, the average yield of the subsurface-packed plats is 0.8 bushel more than the average yield of those not packed. The surface-packed plats also produced

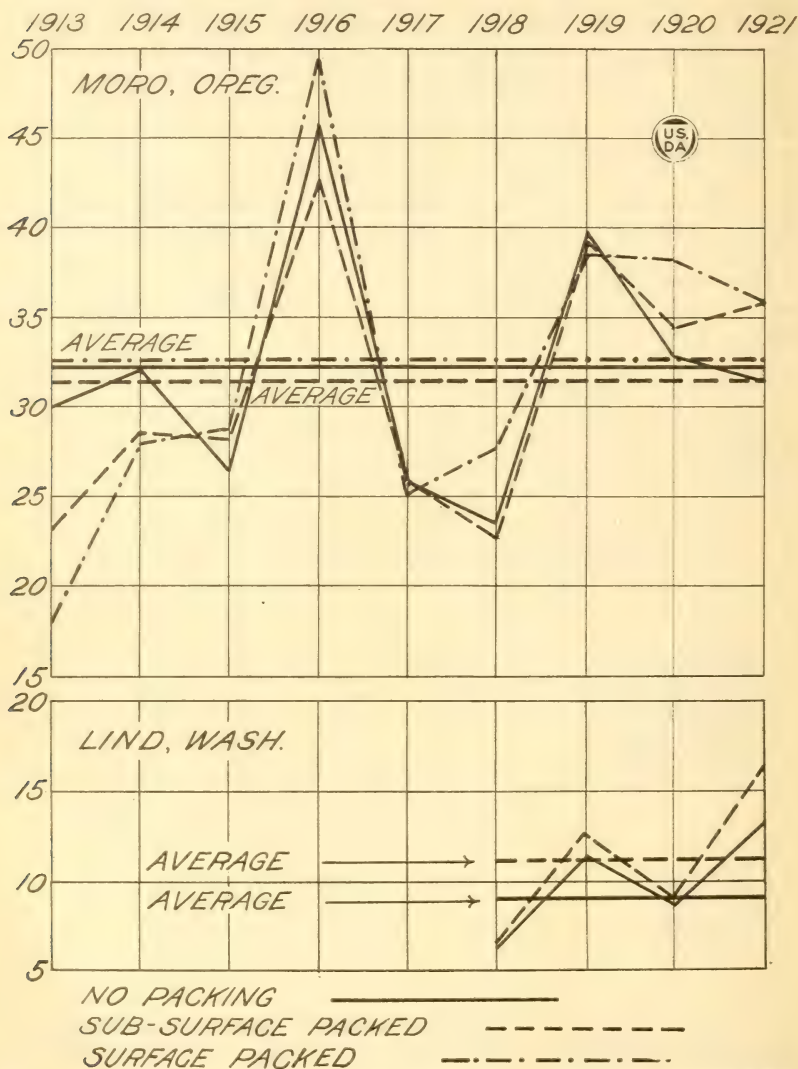


FIG. 17.—Annual and average acre yields, in bushels, of winter wheat in varying numbers of years at Moro, Oreg., and Lind, Wash., when grown after summer fallow for which the land had been plowed in early spring and either not packed or packed with a subsurface or surface packer after plowing.

a slightly higher yield than those not packed, but in this case again the small increases in yield from the packed ground do not appear to be significant when considered in connection with the differences in yields of the check plats used in this experiment, as reported in Table 15.

There apparently was no advantage in using either the subsurface or surface packers at Moro.

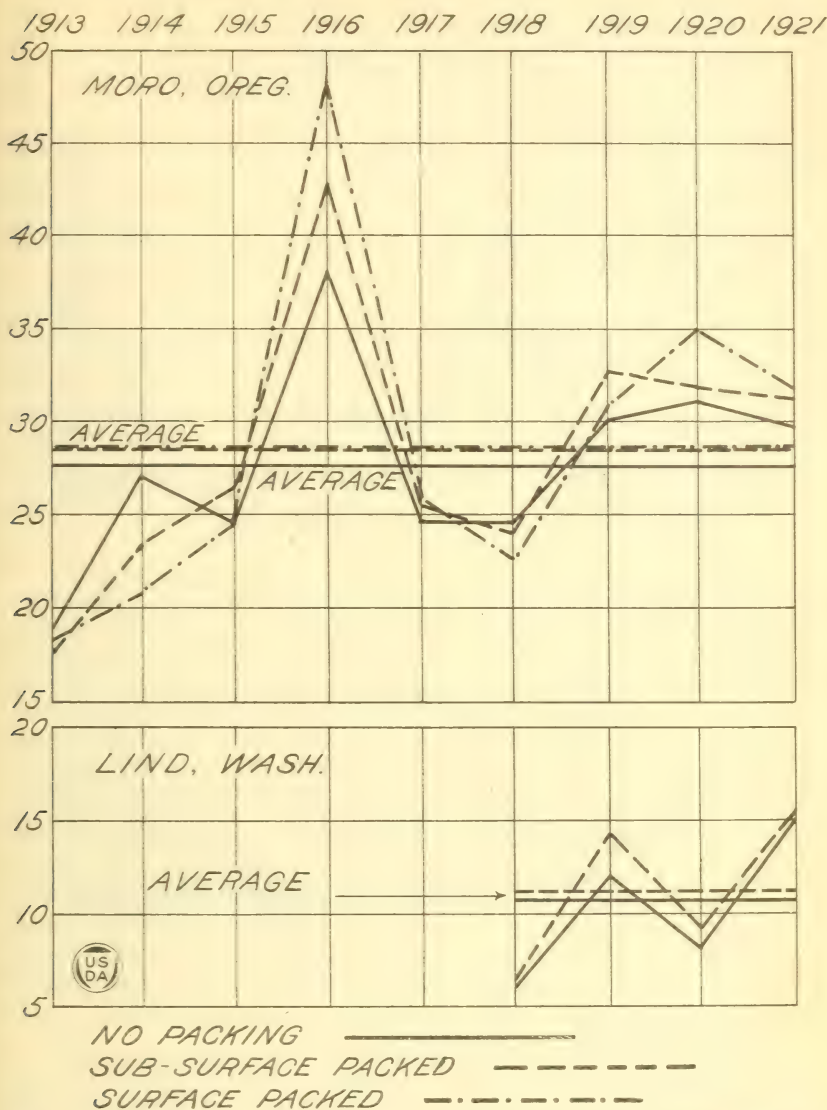


FIG. 18.—Annual and average acre yields, in bushels, of winter wheat in varying numbers of years at Moro, Oreg., and Lind, Wash., when grown after summer fallow for which the land had been plowed in late spring and either not packed or packed with a subsurface or surface packer after plowing.

RESULTS AT LIND.

At Lind the experiments included the use of the subsurface packer on all dates of spring and summer plowing. The results are given in Table 19, and are shown graphically in Figures 17, 18, and 19.

The data in Table 19 indicate that, in contrast to the results at Moro, there were certain beneficial effects in using the packer at

Lind on the two dates of spring plowing. These data are not contradictory, but merely emphasize the fact that differences in soil type, soil-moisture content, and subsequent precipitation may cause entirely different results from the same operation. The heavier soil at Moro, with heavier rainfall, when given any subsequent tillage whatever, tends to settle into a condition more nearly

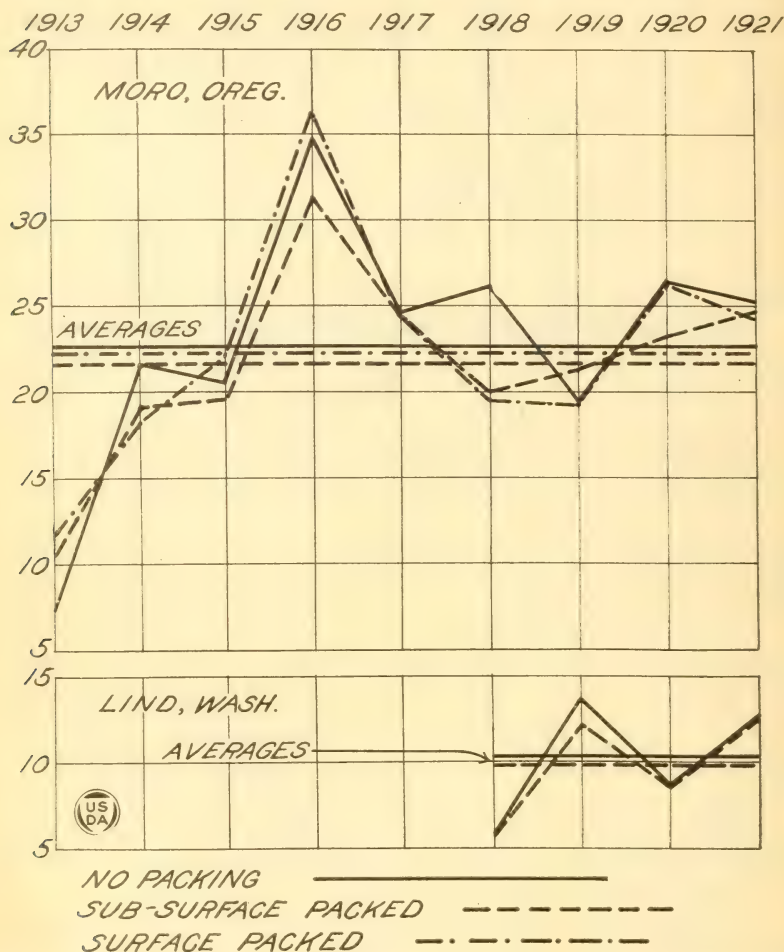


FIG. 19. --Annual and average acre yields, in bushels, of winter wheat in varying numbers of years at Moro, Oreg., and Lind, Wash., when grown after summer fallow for which the land had been plowed in early summer and either not packed or packed with a subsurface or surface packer after plowing.

resembling that treated with the packer than does the lighter soil at Lind under the lighter rainfall. As a result the packer had little effect at Moro, while it had some effect at Lind.

There was no benefit in using the packer at Lind on the June (summer) date, because the soil was less moist and packing did not affect the results.

TABLE 19.—*Annual and average yields of wheat after fallow, packed and not packed, on land plowed on three different dates during the 4-year period from 1918 to 1921, inclusive, at Lind, Wash*

Date of plowing and subsequent treatment.	Yields per acre (bushels).				
	1918	1919	1920	1921	Average.
March (early spring):					
Packed.....	6.3	12.7	9.1	16.2	11.1
Not packed.....	6.1	11.2	8.7	13.2	9.8
April (late spring):					
Packed.....	6.3	14.3	9.0	15.2	11.2
Not packed.....	5.9	12.0	8.1	15.0	10.2
June (early summer):					
Packed.....	5.7	12.3	8.5	12.7	9.8
Not packed.....	5.8	13.8	8.6	12.8	10.2

Despite the possible benefits from using the packer shown by these data, its practical use is doubtful. Weeds grow more rapidly and require more work for their control on packed soil; and especially on light soil types, where the packer is most beneficial, this additional stirring is likely to cause soil drifting by the wind. That the packer has not come into more general use would tend to cast doubt at least on its feasibility.

HARROWING AND WEEDING SUMMER FALLOW.

Experiments to determine the value of frequency of cultivation of summer fallow after plowing were conducted at Moro, Lind, and Nephi. At Moro three methods were tried: (1) No cultivation of the summer fallow after plowing; (2) one harrowing immediately after plowing and no cultivation thereafter; and (3) two harrowings immediately after plowing, with sufficient cultivation with a spike-tooth harrow or rod weeder during the summer to keep the ground free from weeds. A well-tilled fallowed field at the Sherman County Branch Station is shown in Figure 20. Plats in the tillage series treated in each of these three ways are shown in Figures 21 and 22. At Lind two methods of handling fallow were tried: (1) Immediate cultivation after plowing and (2) delayed cultivation, in either case the fallow being kept clean of weeds. At Nephi, no cultivation, moderate cultivation, and frequent cultivation of the fallow also were tested. At all three stations each method of cultivating the fallow was used on different dates or methods of plowing.

RESULTS AT MORO.

At the Moro station the three methods of cultivating fallow were tried on three dates of spring and summer plowing, namely, April 1, May 1, and June 1. Two methods were tried on four kinds of fall plowing, namely, early and late with the disk and early and late with the moldboard plow.

The results obtained, as summarized in Table 20, are in favor of frequent cultivation of the summer fallow for winter wheat except on the June plowing. In this instance the ground was dry when plowed, and cultivation of any kind apparently was of no value. On early spring-plowed fallow at Moro cultivation significantly increased winter-wheat yields but only slightly increased the yields of spring wheat.

TABLE 20.—Average yields of winter and spring wheat at Moro, Oreg., grown after fallow under three methods of cultivation in the 9-year period from 1913 to 1921, inclusive.

Crop and date of plowing.	Yields per acre (bushels).		
	No cultivation.	One harrowing.	Frequent cultivation.
Winter wheat:			
Spring plowing—			
April 1 (early).....	26.6	27.2	31.9
May 1 (late).....	25.9	26.2	27.7
Summer plowing—			
June 1 (early).....	22.4	22.6	22.9
Fall plowing—			
Early.....		24.9	29.5
Late.....		26.2	26.3
Spring wheat:			
Spring plowing—			
Shallow.....	19.6	19.5	20.6
Deep.....	20.2	20.6	20.7

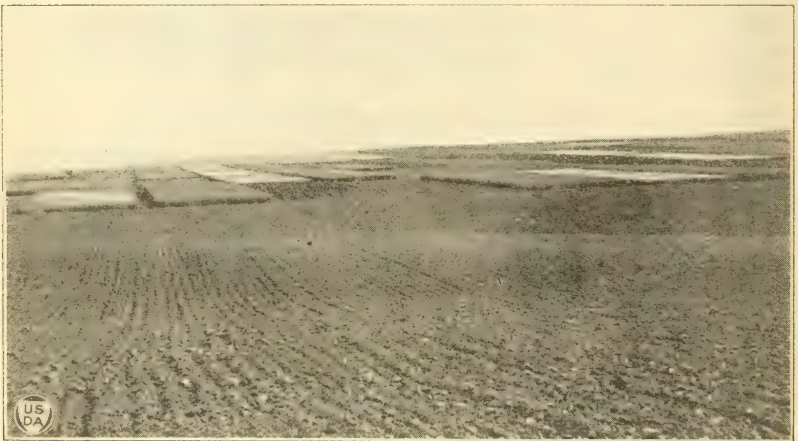


FIG. 20.—Summer fallow in excellent condition at the Sherman County Branch Station, Moro, Oreg. Note the fine clods on the surface and the complete absence of weeds. Rotation and tillage plots are shown in the background.

The yields shown in Table 20 under the heading "Frequent cultivation" were obtained from fallow harrowed twice immediately after plowing, harrowed again about three weeks later or when weeds had started, and weeded with a rod weeder two or three times during the summer. On the land plowed in the fall and on that plowed on April 1 Russian thistles were troublesome on the plats given no cultivation and those harrowed only once after plowing. These weeds were allowed to grow on these plats until they attained considerable size, but they were hoed off each year before maturing seed. This weed growth undoubtedly was one cause of the reduced yields on these plats. On the land plowed on May 1 there usually were very few weeds on the fallow and not enough in any year to be a factor in reducing wheat yields. On land plowed on June 1 no weeds were able to grow, on account of the dry soil.

Table 21 contains a summary of all the results obtained in the tillage experiments with winter wheat at Moro.



FIG. 21.—View of a portion of the tillage experiments at Moro, Oreg., in 1922. At left, plat given frequent cultivation; at right, plat given no cultivation after plowing. The furrows in the plat cultivated frequently are made by the rod weeder.

TABLE 21.—Summary of yields of Turkey winter wheat obtained in tillage experiments at Moro, Oreg., conducted on spring and summer plowing in nine years, 1913 to 1921, and on fall plowing in eight years, 1914 to 1921, inclusive.

Yields per acre under different methods of cultivating summer fallow ¹ (bushels).

Date of plowing.	1 ²	2	3	4	5	6	7	8	9	10	Average. ²
Spring plowing:											
April 1 (early).....	27.2	26.6	29.6	27.2	31.9	30.1	28.5	31.7	31.1	32.2	29.4
May 1 (late).....	27.5	25.9	29.3	26.2	27.7	26.8	25.9	32.5	28.4	28.6	27.1
Summer plowing:											
June 1 (early).....	27.3	22.4	28.3	22.6	22.9	22.8	22.5	28.6	21.7	22.4	23.1
Average.....	27.3	24.9	29.1	25.3	27.5	26.6	25.6	30.9	27.1	27.7	26.5
Fall plowing:											
Early (dry).....	27.6		31.8	24.9	29.5	28.1					27.5
Late (wet).....	26.5			26.2	26.3	25.5		28.4			26.1
Average.....	27.1		31.8	25.6	27.9	26.8		28.4			26.8
Average of all plowings.....	27.2			25.4	27.7	26.7					

¹ The methods of cultivation were as follows:

1. Frequent cultivation; disked in both fall and spring before plowing; clean summer fallow.
2. No cultivation of summer fallow after plowing; weeds hoed off before maturity.
- 3 and 4. Check plats. Frequent cultivation; disked in the spring before plowing; clean fallow.
5. One harrowing immediately after plowing; no further cultivation; weeds hoed off before maturity.
6. Frequent cultivation; no disked before plowing; clean cultivation of fallow.
7. Frequent cultivation; same as No. 5 except that the crop was harrowed in spring.
8. Packed with subsurface packer after plowing and harrowed once only; weeds hoed off before maturity.
9. Packed with subsurface packer and frequently cultivated; clean summer fallow.
10. Packed with surface packer and frequently cultivated; clean summer fallow.

² Yields of check plats, all of which were plowed on Apr. 1, are not included in the averages in this column.

RESULTS AT LIND.

Weed growth has such an important bearing on yield in the portion of the Columbia Basin lying in central Washington that tillage of some sort for weed control can not be omitted in maintaining the fallow. It simply is a question of whether tillage should be given immediately after plowing or whether the tillage should be delayed until weeds start growth. The results obtained are given in Table 22.

From these data it is seen that so long as moisture conditions are favorable, as at the earlier dates of plowing, immediate cultivation may or may not have advantages. As the soil becomes more dry, as in the June plowing, there is nothing to be gained by immediate tillage. In other words, the more dry the general conditions, the less the possible advantages to be gained through immediate cultivation



FIG. 22.—Plats in the tillage experiments at Moro, Oreg., July, 1922. At left, plat given frequent cultivation; at right, plat harrowed once immediately after plowing and not cultivated thereafter. The furrows in the plat cultivated frequently are made by the rod weeder. This weeder is sometimes followed immediately with a spike-tooth harrow to smooth the ground, but usually the fallow is left as shown until seeding time, the ground being smoothed just before sowing.

following the plow. Taken alone these data would not justify such a conclusion, but in conjunction with those from two other stations they tend to point in that direction.

TABLE 22.—Average and annual yields of wheat after fallow cultivated immediately and not cultivated immediately after the plowing, at Lind, Wash., in the years 1918 to 1921, inclusive.

Date of plowing and subsequent treatment.	Annual and average yields per acre (bushels).				
	1918	1919	1920	1921	Average.
March plowing (early spring):					
Immediate cultivation.....	6.2	12.3	9.8	15.7	11.0
Delayed cultivation.....	5.8	13.2	8.3	16.7	11.0
April plowing (late spring):					
Immediate cultivation.....	6.0	14.2	9.2	16.3	11.4
Delayed cultivation.....	5.6	12.7	9.5	13.7	10.4
June plowing (early summer):					
Immediate cultivation.....	5.3	11.3	5.0	12.3	8.5
Delayed cultivation.....	5.6	9.8	6.4	10.3	8.0

RESULTS AT NEPHI.

At Nephi three methods of cultivating the fallow were tried on fall-plowed and on spring-plowed land. In normal cultivation the fall-plowed land was harrowed early in the spring and again in the fall just before seeding. Between these two cultivations usually two weedings were necessary to kill volunteer growth. The spring-plowed land cultivated normally was harrowed after plowing and again before sowing time in the fall. One weeding sometimes was necessary during early summer. Four plats, two in crop each year, were used for this experiment.

In the second method no cultivation was given to the fallow on fall plowing or on spring plowing, but the weeds were kept down by hoeing, with the least possible stirring of the surface soil. Four tenth-acre plats likewise were used for this method, two being fallowed, while the other two produced the crop.

In the third method six plats were required. Two plats were fall plowed and one of them plowed again in the spring. One plat was left in stubble for spring plowing. From June 1 until September 1 all of the fallow plats in the third method were harrowed every two weeks. The results of this experiment are given in Table 23.

TABLE 23.—*Annual and average yields of Turkey winter wheat grown on tenth-acre plats plowed in fall and in spring, or both, with the fallow treated in various ways, at Nephi, Utah, in all or part of the years from 1910 to 1921, inclusive.*

Treatment.	Yields per acre (bushels).													Average.	
	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1910 to 1921	1916 to 1921	
Ordinary cultivation:															
Fall plowing.....	12.0	29.0	22.0	4.0	45.4	31.3	19.3	27.8	16.2	19.3	27.1	48.0	25.1	26.3	
Spring plowing.....	14.0	33.0	22.0	5.0	42.8	31.7	18.3	31.8	14.5	23.7	27.5	38.4	25.2	25.7	
Weeds hoed:															
Fall plowing.....							17.8	31.2	13.2	21.7	23.8	45.7	25.6		
Spring plowing.....							19.5	29.2	13.0	23.0	27.7	42.2	25.8		
Cultivated frequently:															
Fall plowing.....							17.3	27.0	13.6	21.0	23.7	42.3	24.1		
Spring plowing.....							18.3	26.4	13.5	19.3	28.5	35.9	23.6		
Plowed in both fall and spring.....							17.6	28.5	16.7	22.5	28.0	44.3	26.2		

The yields of winter wheat following either spring or fall plowing with ordinary tillage showed no appreciable differences. In the frequent-cultivation experiment the double plowing gave higher yields than either fall plowing or spring plowing alone with frequent tillage in all cases.

In comparing the yields of two normally cultivated plats, one of which was plowed in the fall and the other in the spring, with fall-plowed and spring-plowed plats uncultivated, except for a light hoeing necessary to kill weed growth, the difference in yield of the two fall-plowed plats was only 0.7 bushel and between the two spring-plowed plats only 0.1 bushel. Neither difference was large enough to be significant.

In the frequent cultivation of fallow the difference in yield between fall-plowed and spring-plowed plats was 0.5 bushel in favor

of the former. The double plowing showed an advantage of 2.6 bushels per acre over spring plowing. From results in somewhat similar tests elsewhere double plowing does not seem justified unless necessary to control weeds.

Judged by the results of this experiment from 1916 to 1921, inclusive, it is probable that under conditions similar to those at Nephi, Utah, cultivation other than that required to control weeds does not pay for the extra labor.

TILLAGE FACTORS INFLUENCING YIELDS AND QUALITY OF WINTER WHEAT.

It has been generally accepted without question that the chief purpose of the summer-fallow system is to save moisture for use by the crop during the next season. There are other effects of tillage, however, which have a very important bearing on production and should not be overlooked in considering the problem of the fallow.

Indirectly, because of its influence on soil temperature, aeration, moisture location, etc., tillage has a very marked effect in promoting the activities of soil bacteria; and as a result of this activity and the direct effect of soil stirring and moisture additions the chemical make-up of the soil and consequently the availability of plant food are very materially altered by tillage.

At Lind in the past four seasons and at Moro in the past two seasons the moisture studies of the summer-fallow tillage experiments were accompanied by soil studies of nitrate nitrogen, and while not yet conclusive these studies brought out certain interesting facts. It is not intended to present the data obtained from these studies in this bulletin, yet this phase of tillage effects is so important that it should at least be briefly considered.

Each year there were differences in yield from different methods of fallow treatment, and the moisture studies show that these yield differences were not entirely attributable to moisture variations. In a season when rainfall is comparatively abundant, the entire soil body to the depth ordinarily reached by plant roots may be filled with moisture, and in such cases variations in yield can not be attributed to differences in moisture supply. The nitrate-nitrogen studies show, however, that early clean tillage, in particular, promotes the development of nitrate nitrogen in the soil and that after a year of fallow there are much larger supplies of this plant food in those soils receiving early clean tillage than in those plowed at a late date or on which weeds have been allowed to grow. In years of abundant moisture the yields very closely parallel the soil content of nitrate nitrogen, provided this available nitrogen is not removed by leaching during the winter following the year of fallow.

Not only have there been differences in yield but also wide variations in the habit and manner of plant growth and in the quality of the wheat produced on the different fallows. On the June-plowed plats not previously cultivated to keep down weeds and which were low in content of nitrate nitrogen at seeding time, the plants were a lighter green in color, tillered less, had fewer and smaller leaves, grew more slowly, and when mature usually had more slender culms than those plants grown on the early-plowed plats which were cultivated at frequent intervals during the fallow season and had a greater content of nitrate nitrogen in the soil.

Total straw growth has always been greater on the plats with higher nitrate content. At Moro on the June-plowed plats the ratio of grain to straw was about 1 to 1.5, while on the April-plowed plats the ratio of grain to straw was, on the average, about 1 to 2.5. As a result of this greater straw growth, due to the fact that the heavier vegetation more quickly depletes soil moisture, there was a tendency during dry seasons for the crop to burn more readily on the early well-tilled plowing, and also a tendency for grain to be lower in bushel weight because of maturity being hastened. The smaller vegetative growth of the crop on the late-plowed or insufficiently cultivated fallow, on the other hand, did not so rapidly deplete soil moisture, the crop ripened more slowly during dry weather, and as a result produced larger, heavier grain.

The quality of the grain produced varied not only in weight but also in composition. That produced on the poor fallow, low in nitrate content, was large and plump with a higher percentage of yellow berry, while that produced on the well-tilled fallow, high in nitrate content, had a tendency to be somewhat lower in bushel weight, and even if of equal weight had a much smaller percentage of yellow-berry kernels. Analyses showed that the grain from the well-tilled fallow was higher in nitrogen content, and baking tests showed it to be superior in baking quality to that from the poorer fallow.

Considerable moisture is required in the fall to make conditions fit for germination in ground plowed dry or in that from which moisture has been removed by weeds growing on the summer fallow. Ground plowed early in the spring and properly cultivated during the fallow season will require materially less moisture to make a good seed bed. Much heavier seeding is required to secure a good stand of winter wheat on poorly prepared fallow than on that properly handled. Thinner stands on well-tilled early fallow are compensated by greater tillering, due to the more abundant supply of nitrate nitrogen. On the late-plowed or poorly tilled fallow thin stands generally will tend to reduce yields, because there is not enough available nitrogen to promote tillering. This latter statement, of course, applies only during seasons when moisture is not entirely the limiting factor.

An abundant supply of nitrate nitrogen in the soil at the end of the year of fallow is a very important factor in securing a vigorous growth of winter wheat in the fall, and undoubtedly the plants growing on well-tilled summer fallow are much less liable to winterkill than those on more poorly tilled ground.

Crop yields are the net result of the operation of all soil factors and are limited by one or another of these factors as it may be proportionately less favorable than the others. Under dry farming, moisture usually is the limiting factor, but the degree of its importance in this respect varies considerably. Under extreme conditions moisture alone may determine crop yield, but as rainfall becomes more abundant it assumes a place second in importance to available plant food. Between these extremes there is every gradation in the relative importance of these two factors, this gradation extending even to individual localities and varying there with seasonal conditions from year to year.

In the drier districts it may be necessary to think only of moisture in tillage operations, leaving the other factors to care for themselves,

but as conditions become more favorable and moisture is more abundant nitrate nitrogen in particular should receive increasing attention.

HARROWING THE GROWING CROP.

RESULTS AT MORO.

Experiments to determine what effect the harrowing of winter wheat in the spring has on yield were carried on at Moro, Lind, and Nephi. This is a practice that has been quite widely followed by farmers in the West, but one on the value of which there has been considerable dispute. At Moro there were adjacent plats of winter wheat, one harrowed in the spring and the other not harrowed on land plowed for summer fallow on several dates and by different methods, as shown in Table 24. This experiment, therefore, was repeated nine times at Moro in each year since 1913. The yields shown in Table 24 are averages for nine years, 1913 to 1921, for the spring-plowed and summer-plowed plats and for eight years, 1914 to 1921, for the fall-plowed plats.

TABLE 24.—Average yields of Turkey winter wheat from plats harrowed in the spring and not harrowed, at Moro, Oreg., in the nine years, 1913 to 1921, inclusive, for the spring-plowed and summer-plowed and in the eight years, 1914 to 1921, inclusive, for the fall-plowed plats.

Date and method of plowing.	Average yields per acre (bushels).	
	Harrowed.	Not harrowed.
Plowed April 1 (early spring).....	30.1	31.9
Plowed May 1 (late spring).....	26.8	27.7
Plowed June 1 (early summer).....	22.8	22.9
Plowed in early fall (dry).....	28.1	29.5
Plowed in late fall (wet).....	25.5	26.3
Average.....	26.6	27.6

The results shown in Table 24 justify the conclusion that harrowing winter wheat in the spring at Moro decreases yields. The harrowing was done at a time when it was thought it would do the most good and the least damage to the plants. The surface of the soil at Moro gets very hard in the spring and contains numerous shrinkage cracks. Harrowing apparently would put the land in better condition by creating a light mulch and closing the shrinkage cracks, but the yields have nearly always been decreased by the harrowing. Usually the stands were not appreciably reduced, but harrowing frequently set back the wheat so that it was two or three days later in heading and sometimes a day or two later in ripening than that not harrowed. This delayed maturity probably was caused by covering the wheat plants with small clods turned up by the harrow. Occasionally weeds in the grain can be killed by harrowing, but as a general rule the number of weeds that can be killed by spring harrowing of winter wheat is negligible.

RESULTS AT LIND.

At Lind during the period of these experiments fall conditions were so unfavorable that it was impossible to get winter wheat up and into the winter with a vigorous growth. As a result, in the spring all

plants were comparatively small and naturally were more easily torn out by the harrow in any spring cultivation. To meet this condition harrowing was done at varying periods, depending on the size of plants. Because of these factors it took time to develop experiments that are comparable, and while such experiments were conducted each year, results are presented for only the years 1919, 1920, and 1921. Careful plant counts were made before and after each cultivation to determine the effect of the cultivation on stands. The results are presented in Table 25.

In these experiments the first harrowing was given in the spring immediately after the weather warmed up enough for work and at the time farmers ordinarily first harrow the crop. The second and third harrowings were given at 10-day intervals thereafter. The other treatments were given when the plants were at the stage of growth indicated.

The data lead to the conclusion that any cultivation of the crop before it reaches the stage when it is large enough to cover the ground is decidedly injurious to the stand, and even under the severe conditions of the period of these experiments, when thinner stands should have been at a comparatively greater advantage, thinning at this stage did not increase average yields.

TABLE 25.—*Annual and average yields and percentage of loss in stand of Turkey winter wheat in a spring harrowing experiment at Lind, Wash., during the 3-year period from 1919 to 1921, inclusive.*

Harrowing treatment.	Yields per acre and loss in stand.							
	1919		1920		1921		Average.	
	Yield.	Stand loss.	Yield.	Stand loss.	Yield.	Stand loss.	Yield.	Stand loss.
	Bu.	P. ct.	Bu.	P. ct.	Bu.	P. ct.	Bu.	P. ct.
Unharrowed (check).....	13.0	.....	9.4	5.1	14.7	24.2	12.4	.....
Harrowed once.....	12.8	23.7	9.5	27.2	14.3	20.2	12.3	23.7
Harrowed twice.....	11.7	51.6	9.7	35.0	13.6	53.0	11.7	46.5
Harrowed three times.....	10.4	62.9	7.7	52.3	14.5	61.2	10.9	58.8
Harrowed when covering the ground.....	13.3	40.5	10.2	16.5	14.3	32.7	12.6	29.9
Harrowed when covering the ground and when 6 inches high.....	11.2	.....	9.8	8.9	13.5	28.5	11.5	.....

RESULTS AT NEPHI.

At Nephi only two plats were included in the experiments on harrowing growing wheat. Both were plowed in the spring for fallow and cultivated normally during the fallow period. Harrowing was done on one of the plats when the grain was about 5 inches in height; the other was left uncultivated. The results are given in Table 26.

TABLE 26.—*Annual and average yields of Turkey winter wheat, on plats harrowed in the spring and not harrowed at Nephi, Utah, during the 7-year period from 1909 to 1915, inclusive.*

Treatment.	Annual and average yields per acre (bushels).						
	1909	1910	1911	1912	1913	1914	1915
Cultivated.....	8.3	19.0	27.0	14.9	9.8	31.6	15.3
Uncultivated.....	12.7	19.5	27.7	14.9	10.5	28.3	26.0
Average.....							

The results presented in Table 26 show that cultivation of growing wheat was not justified.

RATE-AND-DATE-OF-SEEDING EXPERIMENTS.

The time when wheat is sown and the rate at which it is sown may markedly influence yields. The time and rate of sowing wheat affect the stand obtained, the tillering of the plants, the quantity and length of straw, and the time of ripening. These also may be influenced by other factors, such as viability of the seed, method of seed treatment for bunt, condition of the seed bed, depth of sowing, winterkilling, soil moisture, and plant food in the soil. The reason for a thin stand frequently may be difficult to determine on account of the number of factors involved. A thin stand of wheat generally is not desirable. It gives weeds a better chance to grow and thereby may seriously reduce yields, or in the absence of weeds a thin stand may not produce enough plants or heads to obtain maximum yields. A stand also may be so thick that there will be insufficient moisture to enable the crop to mature properly.

Rate and date of sowing experiments with both winter and spring wheat were carried on at the three stations, Moro, Lind, and Nephi. At each station the experiment was on fallowed ground, plowed early and kept free from weeds.

RESULTS AT MORO.

WINTER WHEAT.

Experiments to determine the best rates and dates of sowing for Turkey winter wheat were conducted at Moro, Oreg., during the six years from 1916 to 1921, inclusive. Rate of sowing experiments were conducted also in 1914 and 1915. The date of sowing was not the same each year, varying according to the time at which moisture conditions were favorable to begin sowing. The earliest date was September 9 and the latest December 1. Five sowings, at about two-week intervals, were made in the fall of 1916, 1917, and 1921, and four sowings in the fall of 1918, 1919, and 1920.

The quantity of seed sown, shown in Table 27 as pecks per acre, indicates where the drill was set and not the actual pounds of seed sown. All the seed was soaked in a standard formaldehyde solution for five minutes to kill bunt spores and allowed to dry about 24 hours before sowing.

Turkey wheat increases in volume from 20 to 30 per cent after treatment. Treated seed does not run through the drill as readily as untreated seed. The actual number of pounds of seed sown was about one-fourth less than that indicated in Table 27.

Table 27 shows that there were rather wide variations each year in the yields of single plats sown at different rates or on different dates. Table 28 gives a summary of the yields obtained in these experiments with winter wheat at Moro, showing only the average acre yields obtained from each rate and date of sowing in the years 1916 to 1921, inclusive.

The two earliest average dates of sowing, September 17 and October 2, gave the highest average yields, as is shown in Tables 27 and 28. The yields obtained from each of the three later sowings, October 14, October 30, and November 19, are significantly less than

those obtained from each of the two early sowings. This is especially true of the two latest dates of sowing.

TABLE 27.—*Annual and average yields of Turkey winter wheat in rate-and-date-of-sowing experiments conducted at Moro, Oreg., during the 6-year period from 1916 to 1921, inclusive.*

Rate of seeding.	Average date of sowing.	Annual and average yields per acre (bushels).						
		1916	1917	1918	1919	1920	1921	6-year average.
2 pecks.....	Sept. 17	33.0	28.3	16.7	31.7	40.0	29.7	29.9
2 pecks.....	Oct. 2	48.3	21.0	22.3	33.0	35.0	46.0	34.3
2 pecks.....	Oct. 14	49.8	14.0	.....	35.3	24.7	34.3	31.6
2 pecks.....	Oct. 30	23.3	13.3	16.3	27.3	24.3	28.0	22.1
2 pecks.....	Nov. 19	21.6	16.0	17.0	.....	.....	23.0	19.4
Average.....	.....	35.2	18.5	18.1	31.8	31.0	32.2	27.8
3 pecks.....	Sept. 17	30.0	34.0	19.0	34.3	43.0	44.3	34.1
3 pecks.....	Oct. 2	41.2	23.0	26.6	31.3	39.3	41.7	33.9
3 pecks.....	Oct. 14	44.0	13.7	.....	38.3	29.0	37.3	32.5
3 pecks.....	Oct. 30	23.3	13.0	16.6	28.7	25.3	28.7	22.6
3 pecks.....	Nov. 19	22.3	17.0	17.3	.....	.....	23.6	20.1
Average.....	.....	32.2	20.1	19.9	33.2	34.2	35.1	29.1
4 pecks.....	Sept. 17	23.7	35.3	20.3	34.0	40.7	42.0	32.7
4 pecks.....	Oct. 2	40.6	22.7	26.0	26.7	37.7	44.0	33.0
4 pecks.....	Oct. 14	35.0	18.3	.....	37.7	26.0	43.7	32.1
4 pecks.....	Oct. 30	33.3	13.7	19.0	33.3	22.0	31.7	25.5
4 pecks.....	Nov. 19	25.3	18.0	20.0	.....	.....	25.7	22.3
Average.....	.....	31.6	21.6	21.3	32.9	31.6	37.4	29.5
5 pecks.....	Sept. 17	23.3	38.3	17.3	36.7	49.3	42.3	34.5
5 pecks.....	Oct. 2	53.0	25.3	25.6	38.0	39.7	41.7	37.2
5 pecks.....	Oct. 14	28.3	20.3	.....	42.0	25.0	39.7	31.1
5 pecks.....	Oct. 30	40.6	13.7	21.0	31.7	21.0	31.3	26.6
5 pecks.....	Nov. 19	30.0	18.6	21.6	.....	.....	25.3	23.9
Average.....	.....	35.0	23.2	21.4	37.1	33.8	36.1	31.1
6 pecks.....	Sept. 17	31.3	34.3	22.0	36.0	42.3	37.7	33.9
6 pecks.....	Oct. 2	25.6	26.7	25.3	34.5	38.7	44.0	32.5
6 pecks.....	Oct. 14	28.0	23.0	.....	40.0	26.3	36.3	30.7
6 pecks.....	Oct. 30	40.0	14.0	27.0	34.7	17.3	27.7	26.8
6 pecks.....	Nov. 19	30.6	20.3	19.0	.....	.....	25.7	23.9
Average.....	.....	31.1	23.7	23.3	36.3	31.2	34.2	29.9
7 pecks.....	Sept. 17	38.3	26.3	24.7	36.3	45.3	42.0	35.5
7 pecks.....	Oct. 2	21.3	27.0	27.7	39.3	40.8	40.0	32.7
7 pecks.....	Oct. 14	30.0	25.3	.....	41.0	27.0	37.0	32.1
7 pecks.....	Oct. 30	41.6	14.5	26.6	32.7	22.3	31.3	28.2
7 pecks.....	Nov. 19	26.3	20.6	23.3	.....	.....	25.7	24.0
Average.....	.....	31.5	22.7	25.6	37.3	33.9	35.2	30.9
8 pecks.....	Sept. 17	38.0	21.0	25.7	32.3	40.3	41.3	34.6
8 pecks.....	Oct. 2	23.0	24.7	29.7	33.8	37.7	39.7	31.4
8 pecks.....	Oct. 14	32.0	26.3	.....	38.3	29.3	39.3	33.1
8 pecks.....	Oct. 30	43.0	14.0	28.7	30.3	25.7	25.0	27.8
8 pecks.....	Nov. 19	24.6	22.6	20.3	.....	.....	26.3	23.5
Average.....	.....	32.1	21.7	26.1	33.6	35.5	34.3	30.5

SUMMARY OF TOTAL AND AVERAGE YIELDS PER ACRE.

Average date of sowing.	Yields at all rates of seeding (bushels).	
	6-year total.	6-year average.
September 17.....	1,411.3	33.6
October 2.....	1,409.2	33.6
October 14.....	1,115.5	31.9
October 30.....	1,076.8	25.6
November 19.....	627.6	22.4

Figure 23 presents in graphic form the average yield obtained from all rates on each of the five dates.

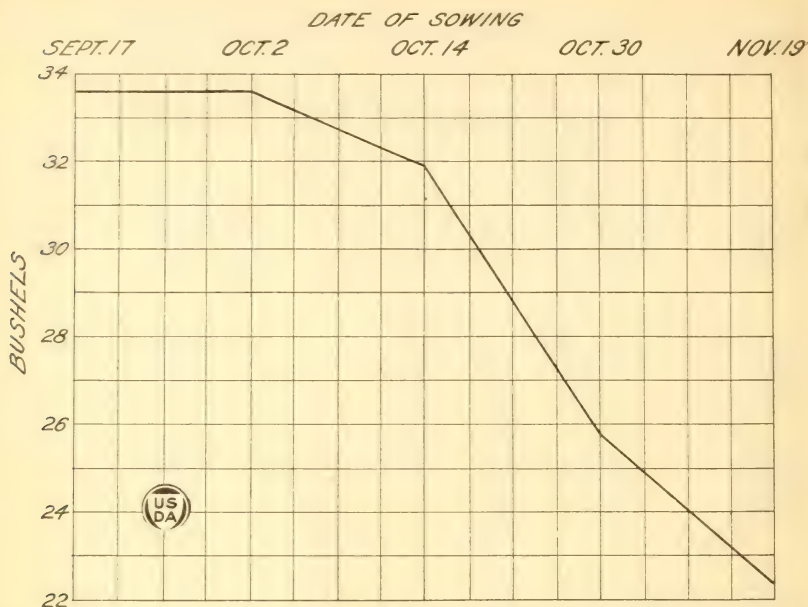


FIG. 23.—Average acre yields of Turkey winter wheat sown at all rates from 2 to 8 pecks per acre on each of five successive dates, September 17 to November 19, in the 6-year period from 1916 to 1921, inclusive, at the Sherman County Branch Station, Moro, Oreg.

TABLE 28.—Average yields of Turkey winter wheat in the rate-and-date-of-seeding experiment at Moro, Oreg., during the 6-year period from 1916 to 1921, inclusive.

Rate of seeding.	Yields per acre (bushels).						
	Average date of seeding.					Average.	
	Sept. 17.	Oct. 2.	Oct. 14.	Oct. 30.	Nov. 19.	Actual.	Net. ¹
2 pecks.....	29.9	34.3	31.6	22.1	19.4	27.4	26.9
3 pecks.....	34.1	33.9	32.5	22.6	20.1	28.9	28.1
4 pecks.....	32.7	33.0	32.1	25.5	22.3	29.1	28.1
5 pecks.....	34.5	37.2	31.1	26.6	23.9	30.7	29.4
6 pecks.....	33.9	32.5	30.7	26.8	23.9	29.5	28.0
7 pecks.....	35.5	32.7	32.1	28.2	24.0	30.5	28.7
8 pecks.....	34.6	31.4	33.1	27.8	23.5	30.1	28.1
Average.....	33.6	33.6	31.9	25.6	22.4	29.4	28.2

¹ Average yield, less the quantity sown.

The time of emergence of the winter-wheat plants has not always borne a consistent relation to time of sowing. In the autumn of 1917 rains came so late that the wheat sown on the first three dates emerged at the same time. In the other four years there was sufficient moisture in the soil so that emergence of the early-sown wheat occurred within 7 to 20 days after sowing. Late-sown winter wheat usually does not emerge for about a month, on account of the cooler weather prevailing. Sometimes the plants of the late-sown wheat

do not emerge until early spring. The dates of sowing, the dates of emergence, and the number of days from sowing to emergence are shown in Table 29.

TABLE 29.—*Dates of sowing, dates of emergence, and number of days from sowing to emergence of Turkey winter wheat sown on various dates at Moro, Oreg., during the 8-year period from 1914 to 1921, inclusive.*

Date sown.	Date emerged.	Time from sowing to emergence.	Date sown.	Date emerged.	Time from sowing to emergence.
Season of 1914:		Days.	Season of 1919:		Days.
Sept. 23.....	Oct. 8	15	Sept. 9.....	Sept. 16	7
Season of 1915:			Sept. 23.....	Oct. 2	9
Oct. 21.....	Nov. 7	17	Oct. 10.....	Nov. 5	26
Season of 1916:			Oct. 25.....	Nov. 20	26
Sept. 18.....	Sept. 25	7	Season of 1920:		
Oct. 2.....	Oct. 17	15	Sept. 16.....	Sept. 25	9
Oct. 18.....	Nov. 5	18	Sept. 30.....	Oct. 16	17
Nov. 3.....	(1)	.....	Oct. 15.....	Nov. 22	38
Nov. 15.....	(1)	.....	Oct. 29.....	(1)	.....
Season of 1917:			Season of 1921:		
Sept. 22.....	Oct. 12	20	Sept. 8.....	Sept. 17	9
Oct. 7.....	Oct. 25	18	Sept. 22.....	Oct. 1	8
Oct. 21.....	(1)	.....	Oct. 7.....	Oct. 22	15
Nov. 6.....	(1)	.....	Oct. 21.....	Dec. 4	44
Dec. 1.....	(1)	.....	Nov. 3.....	(1)	.....
Season of 1918:					
Sept. 27.....	Dec. 17	81			
Oct. 11.....	do.....	67			
Nov. 5.....	do.....	42			
Nov. 27.....	(1)	.....			

¹ Did not emerge until spring.

Table 30 shows the yields obtained by sowing Turkey winter wheat at rates varying from 2 to 8 pecks per acre, in the eight years, 1914 to 1921, inclusive. Only one date of sowing is included for

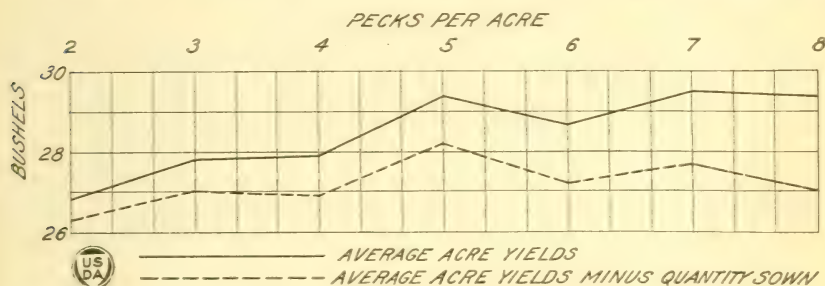


FIG. 24.—Average actual acre yields and average net acre yields obtained from sowing Turkey winter wheat at different rates, varying from 2 to 8 pecks per acre, in the 8-year period from 1914 to 1921, inclusive, at the Sherman County Branch Station, Moro, Oreg. The net yields are the actual yields minus the quantity sown.

1914 and 1915, but the yields for these years are averages obtained from duplicate tenth-acre plats. In the years 1916 to 1921, inclusive, the yields from each rate are averages of the three twentieth-acre plats used for the three earliest dates of sowing, as shown in Table 27. The results are summarized graphically in Figure 24.

The average yields obtained from the different rates of sowing are remarkably similar, indicating that on well-cultivated summer-

fallowed ground the rate of sowing of winter wheat may not be an important factor in influencing yields. From the standpoint of the farmer, however, there is a considerable advantage in sowing the wheat thickly enough to insure good stands. A thin stand of wheat allows so much space for weeds to grow that yields may be reduced on that account. Thick sowing, therefore, has the advantage of suppressing weed growth.

TABLE 30.—*Annual and average yields of Turkey winter wheat in the rate-of-sowing experiments conducted at Moro, Oreg., in the 8-year period from 1914 to 1921, inclusive.*

Rate of seeding.	Annual, total, and average yields per acre (bushels). ¹										Average.	
	1914	1915	1916	1917	1918	1919	1920	1921	Total.			
											Actual.	Net.
2 pecks.....	12.6	15.4	43.7	21.1	18.4	33.3	33.2	36.6	214.3		26.8	26.3
3 pecks.....	12.6	15.0	38.4	23.6	20.7	34.6	37.1	41.1	223.1		27.8	27.0
4 pecks.....	14.1	18.7	33.1	25.4	21.8	32.8	34.8	43.2	223.9		27.9	26.9
5 pecks.....	13.3	19.5	34.9	28.0	21.3	38.9	38.0	41.2	235.1		29.4	28.2
6 pecks.....	16.4	20.0	28.3	28.0	24.8	36.8	35.8	39.3	229.4		28.7	27.2
7 pecks.....	17.5	20.3	29.9	26.2	26.3	38.9	37.7	39.6	236.4		29.5	27.7
8 pecks.....	17.5	20.8	31.0	24.0	28.0	34.8	38.8	40.1	235.0		29.4	27.0

¹ For 1914 and 1915 the yields are averages obtained from duplicate tenth-acre plats. For 1916 to 1921, inclusive, the yields are averages obtained from the three twentieth-acre plats used for the three earliest dates of sowing each year.

SPRING WHEAT.

Experiments combining rates and dates of sowing have been conducted with Pacific Bluestem wheat at Moro in the seven years 1912 to 1918, inclusive. This variety was sown early and late in the spring at rates varying from 2 to 8 pecks per acre. After 1918 only the early date was used. In 1919 this variety was sown at rates varying from 4 to 8 pecks, and in 1920 at rates from 5 to 8 pecks. The results of this experiment are shown in Table 31.

TABLE 31.—*Annual and average yields of Pacific Bluestem spring wheat at Moro, Oreg., sown early and late in the spring at rates varying from 2 to 8 pecks in part or all of the years 1912 to 1920, inclusive.*

Time and rate of seeding.		Annual, total, and average yields per acre (bushels).												
		1912	1913	1914	1915	1916	1917	1918	1919	1920	Total.	Average.		
												7 years, 1912 to 1918.	9 years, 1912 to 1920.	Net.
Early spring:		Mar. 25.	Mar. 25.	Mar. 26.	Mar. 22.	Mar. 31.	Apr. 6.	Mar. 19.	Mar. 25.	Apr. 2.			Mar. 27.	
2 pecks		7.0	18.5	17.5	18.6	23.2	12.1	15.7	-----	-----	112.6	16.1	-----	15.6
3 pecks		8.8	17.5	15.5	18.6	23.3	15.2	15.7	-----	-----	114.6	16.4	-----	15.6
4 pecks		13.6	20.8	14.5	15.1	23.0	15.7	17.3	22.6	-----	142.6	17.1	-----	16.1
5 pecks		12.5	21.3	17.8	17.2	23.0	17.9	18.0	24.8	18.6	171.1	18.2	19.0	17.7
6 pecks		10.5	18.3	16.3	20.6	19.3	18.1	18.0	22.9	16.7	160.7	17.3	17.9	16.4
7 pecks		13.1	20.0	17.3	18.0	19.3	17.3	15.3	22.8	19.8	162.9	17.2	18.1	16.3
8 pecks		13.1	20.0	18.1	19.2	24.0	20.8	15.5	23.6	18.5	172.8	18.7	19.2	17.2
Late spring:		Apr. 26.	Apr. 25.	Apr. 16.	Apr. 15.	May 1.	Apr. 28.	Apr. 22.				Apr. 23.		
2 pecks		7.8	10.5	13.7	10.4	18.8	14.7	9.7	-----	-----	85.6	12.2	-----	11.7
3 pecks		15.5	10.0	11.7	10.4	20.5	13.3	9.7	-----	-----	91.1	13.0	-----	12.3
4 pecks		11.8	7.7	8.7	11.1	18.8	13.6	14.3	-----	-----	86.0	12.3	-----	11.3
5 pecks		14.0	7.6	5.3	10.5	22.6	13.3	12.0	-----	-----	85.3	12.2	-----	11.0
6 pecks		15.1	8.3	3.7	11.4	20.2	12.8	12.7	-----	-----	84.2	12.0	-----	10.5
7 pecks		15.5	10.4	4.0	12.8	17.7	12.0	12.0	-----	-----	84.4	12.1	-----	10.4
8 pecks		15.5	13.1	3.7	10.2	19.6	11.8	11.0	-----	-----	84.9	12.1	-----	10.1

The highest average yields were obtained from the early sowing. On account of its earlier maturity early-sown spring grain usually outyields late-sown grain in the Columbia Basin district. Comparing the rates of sowing, it will be noted from Table 31 that the highest average net yield was obtained from the 5-peck sowing on the early date and from the 3-peck sowing on the late date. As with the winter wheat the difference in the yields obtained from the varying rates is not great except in the case of late sowing, where the thinner rates consistently give the higher yields.

TABLE 32.—*Annual and average yields of Marquis spring wheat sown at Moro, Oreg., at various rates per acre in the 5-year period from 1917 to 1921, inclusive.*

Rate of seeding.	Annual, total, and average yields per acre (bushels).							
	1917	1918	1919	1920	1921	Total.	Average.	
							Actual.	Net.
	<i>Apr. 5.</i>	<i>Apr. 11.</i>	<i>Mar. 25.</i>	<i>Apr. 2.</i>	<i>Mar. 30.</i>		<i>Apr. 3.</i>	
4 pecks.....	16.0	14.9	18.7	18.6	20.3	88.5	17.7	16.7
5 pecks.....	18.7	18.2	18.9	16.5	19.7	92.0	18.4	17.2
6 pecks.....	17.9	18.6	18.7	20.0	20.3	95.5	19.1	17.6
7 pecks.....	21.6	18.6	20.0	17.8	18.9	96.9	19.4	17.6

In Table 32 data are given on a rate-of-sowing experiment with early-sown Marquis spring wheat for the years 1917 to 1921, inclusive. The results shown in the table are the yields obtained from single twentieth-acre plats each year. The results of the four years indicate a slight advantage from the heaviest rates used, viz, 7 and 8 pecks per acre.

RESULTS AT LIND.

WINTER WHEAT.

Because of the very unfavorable fall conditions which prevailed at Lind experiments on rates and dates of seeding with winter wheat have been very unsatisfactory. The most that can be learned from the date-of-seeding experiments is the comparative merits of seeding in the dry soil before rains and waiting until after the rains before seeding. Results of experiments on dates of seeding winter wheat are given in Table 33.

TABLE 33.—*Annual yields and stands of Turkey wheat sown at the rate of 60 pounds per acre in date-of-seeding experiments at Lind, Wash., during the 3-year period from 1919 to 1921, inclusive.*

Time of seeding.	Stands (plants per acre) and yields per acre.					
	1919		1920		1921	
	Stand.	Bushels.	Stand.	Bushels.	Stand.	Bushels.
Early.....	220,000	15.8	128,000	9.2	527,000	12.2
Midseason.....	380,000	16.9	164,000	9.8	776,000	11.2
Late.....	375,000	13.9	180,000	10.5	941,000	11.5

Conditions varied so greatly from season to season that yearly data can not safely be averaged. In the fall of 1918 dry weather was continuous and conditions were so unfavorable that no seeding of any sort was attempted previous to October 1. Rains came about October 25, and second seedings were put in at this date, the late seedings being made on November 15. In 1919 fall conditions seemed somewhat more favorable, and the earliest seedings were made on September 15 and second and third seedings on October 15 and November 15. The early promise did not materialize, however, and no rains in any quantity came before November 15. As a result of these unfavorable seasonal conditions emergence of both crops occurred in midwinter. In the fall of 1920, on the other hand, some rain came comparatively early, and while not of enough volume to promote the best growth and development the plants from the first seeding date made some growth before the others emerged. These light rains later largely evaporated, so that the later seedings also emerged during midwinter.

Remembering that for the 1919 crop rains in quantity came at the time of the second seeding, for the 1920 crop at the time of the late (third) seeding, and for the 1921 crop with the first seeding, the data indicate that under very dry conditions nothing is gained by seeding in the dry soil before fall rains. This is the most that can be deduced from the results of these experiments.

The data covering the rate of seeding are given in Table 34. Because of the same unfavorable conditions applying to the date-of-seeding results, the results on rate of seeding are equally unsatisfactory and the averages equally invalid.

TABLE 34.—*Annual actual and net acre yields of Turkey winter wheat in rate-of-seeding experiments on various dates at Lind, Wash., during the 3-year period from 1919 to 1921, inclusive.*

Time and rate of seeding.		Actual and net annual and average yields per acre (bushels).							
		1919		1920		1921		Average. ¹	
		Actual.	Net.	Actual.	Net.	Actual.	Net.	Actual.	Net.
Early date:									
2 pecks.....				7.1	6.6	13.0	12.5	10.1	9.6
3 pecks.....				7.5	6.7	12.1	11.3	9.8	9.0
4 pecks.....	13.7	12.7		9.7	8.7	12.2	11.2	11.0	10.0
5 pecks.....				8.8	7.5	12.0	10.7	10.4	9.1
6 pecks.....				9.8	8.3	11.0	9.5	10.4	8.9
7 pecks.....				10.3	8.5	12.1	10.3	11.2	9.4
8 pecks.....				10.5	8.5	11.5	9.5	11.0	9.0
Middle date:									
2 pecks.....	14.7	14.2		9.1	8.6	11.8	11.3	11.9	11.4
3 pecks.....	16.8	16.0		8.8	8.0	10.9	10.1	12.2	11.4
4 pecks.....	15.8	14.8		10.7	9.7	11.2	10.2	12.6	11.6
5 pecks.....	16.0	14.7		9.0	7.7	10.5	9.2	11.8	10.5
6 pecks.....	18.3	16.8		9.0	7.5	11.0	9.5	12.8	11.3
7 pecks.....	14.7	13.0		8.7	7.0	10.2	8.4	11.2	9.5
8 pecks.....	15.7	13.7		8.8	6.8	10.2	8.2	11.6	9.6
Late date:									
2 pecks.....	10.0	9.5		7.0	6.5	11.0	10.5	9.3	8.8
3 pecks.....	12.2	11.4		9.3	8.5	11.4	10.6	11.0	10.2
4 pecks.....	11.8	10.8		10.5	9.5	11.5	10.5	11.3	10.3
5 pecks.....	13.8	12.5		10.5	9.2	10.8	9.5	11.7	10.4
6 pecks.....	13.3	11.8		10.8	9.3	10.5	9.0	11.5	10.0
7 pecks.....	13.3	11.5		11.5	9.7	10.0	8.2	11.6	9.8
8 pecks.....	14.0	12.0		10.1	8.1	10.0	8.0	11.4	9.4

¹ Average yields from the 4-peck rate on early date of seeding are for two years only (1920 and 1921).

Yields are not uniform in their relation to rate of seeding in these experiments, other factors apparently having more bearing on results than the rate of seeding. Variations tend in both directions, yet center more or less around the 4-peck rate. The data do not conclusively point to any rate as best for any particular condition, but since farm practice is already based on the 4-peck rate of seeding the experimental evidence at least does tend to confirm this practice.

SPRING WHEAT.

At Lind the experiments with spring wheat to determine the best rates and dates of seeding did not include the rate factor for any date other than the first. The date of first seeding in the spring was determined entirely by seasonal conditions and during the experiments varied from March 12, in 1919, to April 3, in 1917. In any case the first seeding date was always the earliest date in the spring at which seeding could be done. The two later dates were at regular intervals of one month after the first. The results are given in Table 35.

TABLE 35.—*Annual and average yields of Early Baart spring wheat in date-of-seeding experiments at Lind, Wash., during the 5-year period from 1917 to 1921, inclusive.*

Time of seeding.	Annual and average yields per acre (bushels).					
	1917	1918	1919	1920	1921	Average.
Early.....	9.4	6.6	10.4	10.3	9.1	9.1
Medium.....	5.1	5.3	10.0	9.9	8.2	7.7
Late.....	2.6	3.3	8.0	8.6	5.1	5.5

These data point conclusively to the advantages of early seeding for spring wheat.

The rate of seeding does not seem to be a particularly important factor so long as the rate is heavy enough to provide a stand capable of competing with weeds. The results of rate-of-seeding experiments with spring wheat are given in Table 36.

TABLE 36.—*Annual and average yields of Early Baart spring wheat in rate-of-seeding experiments at Lind, Wash., during the 5-year period from 1917 to 1921, inclusive.*

Rate of seeding.	Annual and average net yields per acre (bushels).					
	1917	1918	1919	1920	1921	Average.
2 pecks.....	5.2	6.8	7.0	9.6	3.0	6.3
3 pecks.....	7.2	6.4	9.3	10.4	4.0	7.5
4 pecks.....	8.4	5.6	9.4	9.3	8.1	8.1
5 pecks.....	8.0	4.4	9.1	9.6	7.8	7.8
6 pecks.....	7.7	5.0	9.1	8.1	8.0	7.8
7 pecks.....	7.6	3.6	9.3	7.8	8.7	7.4
8 pecks.....	7.2	3.3	9.8	7.2	8.5	7.2

These data indicate that a rate of 4 pecks gives the best average net yield in the 5-year period, and considering the superior advantages of heavier stands in competing with weeds and wireworms a rate of 4 pecks or more probably is advisable.

RESULTS AT NEPHI.

No experiments combining dates and rates of seeding were conducted at Nephi with either winter or spring wheat, but rate-of-seeding experiments were conducted during the years 1910 and 1911 and 1913 to 1917, inclusive, and in 1919 to 1921, inclusive.

The yields from these experiments are given in Table 37. Both Turkey and Kofod winter wheats were used, but only the results from Turkey are given. The experiment was not conducted in 1912, and the formaldehyde treatment or some physical injury to the grain in 1918 caused a complete failure. From 1910 to 1916 single tenth-acre plats were used, and from 1917 to 1921 each rate was duplicated on twentieth-acre plats. The 7-peck and 8-peck sowings were added in 1917.

It is evident from the data in Table 37 that as the rate of seeding was increased up to 6 pecks, the yields increased regularly. The 7-peck and 8-peck sowings were not included a sufficient length of time for the results to be comparable with those from the lighter rates. A peculiar feature in respect to drought and stand occurred in 1919. The season was one of the driest on record at Nephi, and yet the higher rates of seeding not only gave the largest yields, but during the whole summer the plants showed more vigor than plants on plats where seeding was at a lower rate.

TABLE 37.—*Annual and average actual and net yields from Turkey winter wheat in rate-of-seeding experiments at Nephi, Utah, during the 9-year period from 1910 to 1921, inclusive.*

Rate of seeding.	Yields per acre (bushels).												
	1910	1911	1913	1914	1915	1916	1917	1919	1920	1921	Average.		
											1910 to 1921	1917 to 1921	Net ¹ 1917 to 1921
2 pecks.....	16.0	23.5	0	25.7	28.0	22.5	17.4	16.3	10.2	22.7	18.2	16.6	16.1
3 pecks.....	19.3	21.3	2.7	32.8	20.8	20.2	19.6	18.1	15.7	27.5	20.8	20.2	19.5
4 pecks.....	19.3	28.7	3.0	38.7	34.5	20.8	21.6	19.4	19.0	30.3	23.5	22.6	21.6
5 pecks.....	19.3	33.7	2.9	44.2	37.3	22.1	22.3	21.5	19.2	37.2	26.0	25.0	23.7
6 pecks.....	17.0	30.3	3.0	46.5	36.7	25.8	24.8	21.0	20.3	40.3	26.6	26.6	25.1
7 pecks.....	.....	.....	.....	.....	.....	.....	26.3	23.5	19.0	41.2	.....	27.5	25.7
8 pecks.....	.....	.....	.....	.....	.....	.....	28.3	22.5	19.2	43.2	.....	28.3	26.3

¹ Quantity sown deducted from actual yield.

DEPTH-OF-SEEDING EXPERIMENTS.

RESULTS AT MORO.

The stand of winter wheat may be greatly influenced by the depth of sowing. Better germination of winter wheat usually is obtained from shallow seeding, especially if the wheat is sown very late when the ground is cold. As it generally is desirable to have a comparatively thick stand of winter wheat, farmers in the Columbia Basin section usually sow wheat from $1\frac{1}{2}$ to 3 inches deep.

Experiments to determine the effect on yield of different depths of sowing winter wheat were conducted at Moro, Oreg., and Lind, Wash. In 1914 at Moro winter wheat was sown on August 26, before the autumn rains, 2 and 4 inches deep, in duplicate plats at 5 pecks per

acre, one plat being sown with seed treated with formaldehyde and the other plat with untreated seed. The experiment was repeated on September 9. On both dates of sowing an irregular stand was obtained on the plats sown 4 inches deep. On November 5 counts were made of plants emerged on representative areas on each plat, and the results obtained are shown in Table 38.

TABLE 38.—Stand of plants per acre in depth-of-seeding experiments at Moro, Oreg., in 1914.

Time of seeding and treatment.	Depth of sowing.	
	Shallow.	Deep.
Early sowing:		
Seed treated.....	83,000	37,000
Seed not treated.....	180,000	84,000
Late sowing:		
Seed treated.....	104,000	62,000
Seed not treated.....	140,000	120,000
Average.....	127,000	76,000

The average yield obtained from the shallow seeding was 17.3 bushels per acre and from the deep seeding 14.9 bushels per acre. The yields, however, were somewhat influenced by weeds, which were numerous in the thin irregular stand obtained from deep seeding.

Table 39 shows the yields obtained from sowing winter wheat 2 inches deep, 3½ inches deep, and 5 inches deep in the four years 1917, 1918, 1919, and 1921. Sowings were made in duplicate twentieth-acre plats each year. On account of favorable moisture and temperature conditions at the time of sowing, practically no difference was obtained in the stands from the three depths of sowing during any of the years. It will be noted from Table 39 that the average yields obtained from the three depths of sowing were practically identical, indicating that the depth of sowing probably has no influence on the yield if uniform stands are obtained.

TABLE 39.—Annual, total, and average yields of Turkey winter wheat sown at three depths at Moro, Oreg., in the years 1917 to 1919, inclusive, and in 1921.

Depth of seeding.	Annual, total, and average yields per acre (bushels).					
	1917	1918	1919	1921	Total.	Average.
Shallow, 2 inches.....	20.8	26.3	18.6	37.0	102.7	25.6
Middeep, 3½ inches.....	22.0	24.3	19.6	39.8	105.7	26.4
Deep, 5 inches.....	22.2	24.7	20.1	38.6	105.6	26.4
Total.....	65.0	75.3	58.3	115.4	314.0	.....
Average.....	21.7	25.1	19.4	38.4	.....	26.1

RESULTS AT LIND.

WINTER WHEAT.

At Lind, depth-of-seeding experiments were carried parallel to the rate-and-date-of-seeding experiments with both fall and spring wheats. Data for the depth-of-seeding experiment with winter wheat are given in Table 40.

In interpreting these data it must be borne in mind that conclusions based on them are applicable only to conditions similar to those prevailing during the period of these experiments. In the fall of 1918 and in 1919 the seed either remained dormant in the dry soil to be germinated at a later date or it was seeded at the later date under conditions where the soil, even at the shallow depth, remained moist after seeding. For such conditions the most shallow seeding was best. In the fall of 1920, on the other hand, there was some early moisture, followed later by dry weather. In this case the deeper seeding was best even on the early date. The best depth of seeding, therefore, must be determined by conditions.

TABLE 40.—*Annual yields and stands per acre of Turkey wheat sown on three different dates in a depth-of-seeding experiment at Lind, Wash., in the years 1919 to 1921, inclusive.*

Stands (plants per acre) and yields per acre.						
Time and depth of seeding.	1919		1920		1921	
	Stand.	Bushels.	Stand.	Bushels.	Stand.	Bushels.
Early date:						
1 inch.....	220,000	15.8	128,000	9.2	624,000	12.1
2½ inches.....	122,000	13.7	76,000	6.5	756,000	11.9
4 inches.....	64,000	9.0	53,000	5.0	819,000	12.2
Midseason date:						
1 inch.....	350,000	16.9	164,000	9.8	804,000	10.8
2½ inches.....	237,000	16.2	93,000	7.0	844,000	11.7
4 inches.....	166,000	12.6	83,000	6.1	751,000	11.7
Late date:						
1 inch.....	375,000	13.9	180,000	10.5	999,000	11.1
2½ inches.....	358,000	12.6	135,000	9.9	901,000	10.7
4 inches.....	289,000	13.9	147,000	8.8	852,000	10.8

* SPRING WHEAT.

Conditions prevailing at the time spring wheat is sown differ somewhat from those found in the fall when winter wheat is seeded. In the spring the soil is moist, but if the season be dry it may tend to dry more or less rapidly from the surface downward. Data on depth-of-seeding experiments with spring wheat are given in Table 41.

TABLE 41.—*Annual and average yields of Early Baart spring wheat in depth-of-seeding experiments at Lind, Wash., in the years 1917 to 1921, inclusive.*

Depth of seeding.	Annual and average yields per acre (bushels).					
	1917	1918	1919	1920	1921	Average.
1 inch.....	9.4	5.3	9.7	9.6	7.8	8.4
2 inches.....	9.4	6.2	10.4	10.6	8.7	9.1
4 inches.....	9.9	6.4	11.2	10.5	9.1	9.4

These data are distinctly in favor of the deepest seeding. In a season when precipitation is comparatively abundant at the time of seeding, as in 1917, the most shallow seeding may be practically equal to that at the greater depths, but for the drier conditions, on the average, the deep seeding is preferable for spring wheat.

SPACING EXPERIMENTS.

RESULTS AT MORO.

Experiments to determine the effect on yield of sowing wheat in rows spaced different distances apart were conducted at Moro with spring and with winter wheat. Table 42 shows the yields obtained from sowing Turkey winter wheat in rows 7 and 14 inches apart in the years 1917 to 1921, inclusive. Duplicate sowings on twentieth-acre plats were made in each of these years except 1919, when the experiment was repeated four times on twentieth-acre plats. Exactly the same quantity of seed was sown on each plat, the rows 14 inches apart having twice the quantity of seed per row as the rows 7 inches apart. Wheat sown thickly in the row usually emerges more quickly than wheat sown thinly. Thickly sown wheat also grows more rapidly when the plants are young. It will be noted from Table 42 that the average acre yield obtained from the 14-inch spacing is 2.5 bushels less than that obtained from the 7-inch spacing. This difference in yield undoubtedly is significant and indicates that maximum yields of winter wheat can not be obtained by sowing in rows spaced as widely as 14 inches apart.

TABLE 42.—*Annual, total, and average yields of Turkey winter wheat when sown in rows 7 inches and 14 inches apart at Moro, Oreg., in the 5-year period from 1917 to 1921, inclusive.*

Spacings.	Annual, total, and average yields per acre (bushels).						
	1917	1918	1919	1920	1921	Total.	Average.
7 inches.....	20.0	23.0	30.7	26.0	36.7	136.4	27.3
14 inches.....	18.5	20.5	26.7	23.7	34.8	124.2	24.8

In 1916 and 1917 an experiment was conducted to determine the effect on yield of spring wheat and winter wheat of sowing in rows 4, 6, and 8 inches apart. In 1916 wheat was sown also in paired rows 6 inches apart, with a 24-inch spacing between the adjacent pairs. The experiment was conducted on small plats, 8 feet wide and 33 feet long. Duplicate plats were sown at each of three rates of seeding, namely 4, 5, and 6 pecks per acre, on each of the four different spacings. An equal quantity of seed was sown in each of the four different spacings in each rate. The yields obtained in 1916 from each plat are shown in Table 43.

TABLE 43.—*Yields of Pacific Bluestem spring wheat when sown at three different rates and at four different distances between rows at Moro, Oreg., in 1916.*

Rate of seeding.	Yields per plat (pounds).							
	Single rows.						Paired rows, 6 inches apart, 24-inch spacing between pairs.	
	4-inch spacing.		6-inch spacing.		8-inch spacing.			
	Series 1.	Series 2.	Series 1.	Series 2.	Series 1.	Series 2.	Series 1.	Series 2.
4 pecks.....	7.00	8.50	8.00	11.50	7.50	5.00	5.25	4.00
5 pecks.....	10.25	10.50	9.25	10.50	9.50	8.75	4.50	4.00
6 pecks.....	10.00	11.00	9.50	9.00	8.50	8.50	4.50	4.50
Average.....	9.54		9.62		7.96		4.46	

In 1917 this experiment was repeated, except that the wheat was sown in rows 4, 6, 8, and 12 inches apart and two varieties were used. The yields of grain of Kharkof and of Pacific Bluestem in pounds per plat are shown in Table 44.

TABLE 44.—*Yields of Kharkof winter wheat and Pacific Bluestem spring wheat when sown at three different rates and at four different distances between rows at Moro, Oreg., in 1917.*

Variety and rate of seeding.	Yields per plat (pounds).							
	4-inch spacing.		6-inch spacing.		8-inch spacing.		12-inch spacing.	
	Series 1.	Series 2.	Series 1.	Series 2.	Series 1.	Series 2.	Series 1.	Series 2.
Kharkof:								
4 pecks.....	8.0	8.0	8.5	6.0	6.0	8.0	7.0	9.0
5 pecks.....	7.0	8.0	7.0	7.0	5.0	6.5	7.0	6.0
6 pecks.....	6.0	9.0	5.0	8.0	4.0	8.5	5.0	6.5
Average.....	7.7		6.9		6.3		6.7	
Pacific Bluestem:								
4 pecks.....	3.0	4.0	4.0	3.5	2.0	3.5	2.0	3.0
5 pecks.....	4.0	4.5	3.5	4.5	3.5	4.0	3.0	4.0
6 pecks.....	3.0	4.0	4.5	4.0	3.5	4.5	2.0	4.0
Average.....	3.8		4.0		3.5		3.0	

In 1916 the highest yields were obtained from the 4-inch and 6-inch spacings with Pacific Bluestem wheat, as is shown in Table 43. In 1917 slightly higher yields of Kharkof wheat were obtained from the 4-inch spacing, with the yields from the 6, 8, and 12 inch spacings practically identical, as is shown in Table 44. There also was not a wide variation in the yields obtained in 1917 from the Pacific Bluestem sown with the 4, 6, 8, and 12 inch spacings. The 12-inch spacing gave the lowest yield and the 6-inch spacing the highest, as is also shown in Table 44.

SUMMARY.

Wheat is one of the most important farm crops grown in Washington, Oregon, Idaho, and Utah and is the only important commercial crop grown on their nonirrigated lands. Successful dry-farm wheat production in these States is based on alternate years of crop and clean fallow.

Experiments to determine the effect of different tillage methods on the yield of wheat were begun at Nephi, Utah, in 1904, at Moro, Oreg., in 1911, and at Lind, Wash., in 1916, by the agricultural experiment stations of these States in cooperation with the United States Department of Agriculture.

The altitude at Moro is 1,800 feet, and the soil type is silt loam. The altitude at Lind is 1,600 feet and the soil a fine sandy loam. The altitude at Nephi is nearly 6,000 feet and the soil a heavy clay loam.

The average annual precipitation at Moro is 11.52 inches; at Lind, 7.22 inches; and at Nephi, 13.27 inches.

The average evaporation from a free water surface at Moro in the 7-month period, April to October, inclusive, was 44.88 inches; at Nephi, 48.37 inches. No evaporation records were kept at Lind, but other weather data indicate that the evaporation is as great as if not greater than at Moro.

The average frost-free period at Moro is 145 days; at Lind, 136 days; and at Nephi, 111 days.

The fall disking of stubble land plowed early in the spring for fallow decreased winter wheat yields at Moro, Lind, and Nephi. Disking stubble land in the spring before plowing increased yields at Moro and at Lind when the plowing was done as late as June 1, but did not increase yields when the plowing was completed by May 1. Yields of winter wheat after fall-plowed fallow when the stubble was burned and when different quantities of stubble were turned under were identical in a 6-year period at Nephi.

Early spring plowing gave the highest yields of winter wheat at Moro. The average yields of eight tenth-acre plats plowed at different times were:

	Bushels per acre.
Fall plowing, early (dry).....	27.5
Fall plowing, late (wet).....	26.1
Early spring plowing (Apr. 1).....	30.0
Late spring plowing (May 1).....	28.2
Early summer plowing (June 1).....	24.6

The average yields of spring and winter wheat in a 4-year period at Lind were:

	Bushels per acre.
Fall plowing (dry).....	7.2
Fall plowing (wet).....	8.2
Early spring plowing (March).....	10.0
Late spring plowing (April).....	10.2
Early summer plowing (June).....	8.2

The average yields of Turkey winter wheat at Nephi, for a 6-year period from 1916 to 1921, inclusive, were:

	Bushels per acre.
Fall plowing.....	24.5
Early spring plowing.....	24.2
Late spring plowing.....	20.9
Early summer plowing.....	15.4

In depth-of-plowing experiments at Moro in the nine years, 1912 and 1914 to 1921, inclusive, the average acre yield of eight tenth-acre plats of spring wheat and winter wheat plowed early in the spring 5 inches deep was 20.4 bushels, and the average yield of eight tenth-acre plats plowed on the same dates 10 inches deep was 21.3 bushels per acre.

In depth-of-plowing experiments at Lind for the years 1918 to 1921, inclusive, the yields from 4-inch dry fall plowing were higher than from 6-inch dry fall plowing. On wet fall plowing the yields obtained from plowing 4 inches and 6 inches deep were identical. On early spring plowing (March) slightly higher yields were obtained from plowing 8 inches deep. On plowing done in April and June the yields obtained from plowing 4, 6, and 8 inches deep were practically identical.

At Nephi the average yield of winter wheat in the 10 years between 1910 and 1921 on land plowed 10 inches deep was 1 bushel per acre greater than that obtained on land plowed 5 inches deep. The yields from 10-inch plowing were as good as the yields obtained from subsoiling 15 to 18 inches deep. Plowing in the fall and replowing in the spring did not increase winter-wheat yields over those from one plowing.

Packing land with surface or subsurface packers after plowing at Moro did not significantly increase the yields of winter or spring wheat. On land plowed early in the spring slightly higher yields

were obtained at Lind during a 4-year period on land packed with a packer. On land plowed in April the yields at Lind also have slightly favored the plats packed after plowing, while on June-plowed plats the reverse was true.

Frequent cultivation of the summer fallow at Moro resulted in higher average yields of winter wheat on fall-plowed land or on land plowed April 1 and May 1 than no cultivation of the fallow or one harrowing only. Where plowing was done as late as June 1 cultivation of the summer fallow did not increase wheat yields. At Lind there were only slight differences in the yields from the summer fallow receiving immediate tillage as compared with delayed tillage. At Nephi more cultivation than that necessary to control weeds did not prove profitable on the average.

Soil moisture and nitrate studies at Moro and Lind indicate that tillage practices have an important bearing on the accumulation of nitrate nitrogen in the soil. The quantity of nitrate nitrogen in the soil greatly influences the habit of growth of winter and spring wheat and the chemical composition of the wheat kernel.

Experiments to determine the effect on yield of harrowing winter wheat in the spring show that on the average this practice reduced yields at Moro and at Lind. At Nephi it did not have any effect on the average yield of winter wheat.

In the date-of-sowing experiments with winter wheat at Moro in the years 1916 to 1921, inclusive, slightly higher yields were obtained from sowing winter wheat about the middle of September or early in October than on later dates. Yields of winter wheat were significantly decreased when it was sown as late as November 1. The most profitable rate of sowing winter wheat at Moro was with the drill set to sow 5 pecks per acre of treated seed, or approximately 1 bushel per acre of dry seed. With spring wheat the highest yields were obtained at Moro from sowing early in the spring at the rate of 5 pecks per acre.

At Lind slightly higher yields were obtained from winter wheat sown early than from wheat sown midlate or late in the fall. No advantage, however, was found in sowing wheat in dry soil. Experiments to determine the best rate of sowing winter and spring wheats at Lind indicate that the most profitable rate for either is about 4 pecks per acre. Higher yields of spring wheat were obtained at Lind from early sowing.

In the rate-of-sowing experiments with winter wheat at Nephi the highest average yields were obtained by sowing at the rate of 6 pecks per acre when that was the highest rate used, and from 8 pecks per acre after that rate was added.

In an experiment to determine the effect on yield of sowing winter wheat at different depths, no significant difference was obtained at Moro during a 4-year period from wheat sown 2, 3½, and 5 inches deep. The depth of sowing winter wheat had an important influence on stand, especially when the wheat was sown late. At Lind there was an advantage from the shallow seeding of winter wheat. Sowing spring wheat at a depth of 4 inches gave slightly higher yields at Lind than sowing 1 and 2½ inches deep.

In a spacing experiment at Moro the same quantity of winter wheat sown in rows 7 inches apart produced higher acre yields than when sown in rows 14 inches apart.

